SCIENCE AND MANKIND

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HUNGER AND FOOD

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FEDERATION OF SCIENTIFIC WORKERS

SCIENCE AND MANKIND

HUNGER AND FOOD

EDITED BY
JOSUE DE CASTRO

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WORLD FEDERATION OF SCIENTIFIC WORKERS

HUNGER AND FOOD

Special edition of

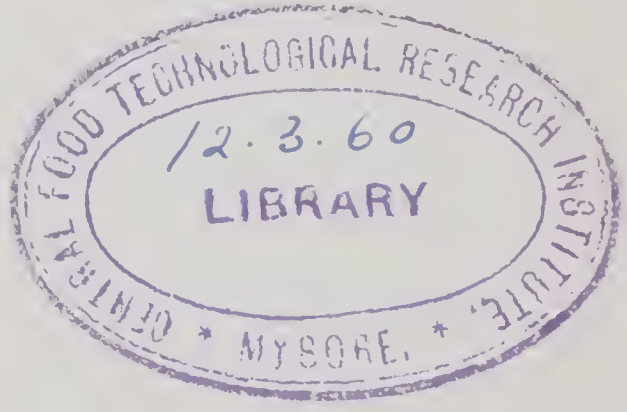
SCIENCE AND MANKIND,

edited by Professor Josué de Castro.

former Chairman of the Executive Council of FAO

and individual member of the World Federation

of Scientific Workers



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FOOD AND HEALTH*

by

Professor Josué de Castro, Institute of Nutrition, Rio de Janeiro

The French sociologist, Father Joseph Lebret, said recently that in view of its human implications hunger has been the greatest discovery of the twentieth century. Perhaps it would be better to say "rediscovery": with the impact of two world wars and their sinister consequences, the western world rediscovered the phenomenon of hunger, which, following the last famine in Europe, had lain unknown, forgotten by the civilized world, for more than a century. Nevertheless, hunger had continued to exist in various continents, crushing down and degrading great masses of people.

For a long time there was a sort of taboo on this problem, but today that taboo is broken. World conscience has awakened to its black reality and dangerous consequences. Now men of science as well as statesmen have begun to take an active interest in analysing and understanding more profoundly this problem of universal hunger, considered both by a scientist such as Lord Boyd Orr and by a politician such as Harold Wilson, as the gravest and most urgent problem facing humanity.

It was because of the urgency of the problem of hunger and food, and the pressing need to study its biological, economic and social aspects, in order to provide a clear idea of its complexity and its possible solutions, that it was decided to devote a special number of *Science and Mankind*, published by the World Federation of Scientific Workers, to the problem of Hunger and Food. The aim was to consider the problem of hunger as the most generalized and widespread of all diseases, and to study the means potentially available to science for combatting this universal evil.

The most modern studies in social medicine have demonstrated that there is no greater influence on vital equilibrium and maintenance of health levels than the food factor. It is perhaps through the nutritional link that the environment — soil and climate — even though indirectly, exerts its most decisive influence on the physical vigour, productive capacity and resistance to disease of human groups.[3]

As a result of long-continued ecological research it has become clear that the impact of a given geographical area on the conditions of human life, determining a whole series of unbalances, deficiencies and alterations of health, operates through nutritional defects and disproportions much more than through the direct action of climate upon men.

In opening the debate on this important subject, I wish merely to bring out in this introductory chapter, in a general way, the importance of this

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* Based on a paper read at the Second Conference on Health and Living Conditions — Cannes, 1957.

factor in the development of disease, or I might say, in the loss of vital equilibrium, leaving for the other contributors a more detailed analysis of the subject, as they take up its various specific aspects. My purpose is only to present a general or panoramic view of the problem, and to analyse the mechanism by which alimentation may have a part in the appearance and evolution of human diseases.

If we examine the subject objectively, we must stress the fact that the food factor may influence the balance of health, causing, contributing to or hastening the development of disease, in various distinct ways. The first possibility is that failures or defects of nutrition may provoke the appearance of primary nutritional syndromes, also called deficiency diseases. These deficiency states may appear in their typical forms, with the clear characteristics of clinical syndromes, such as pellagra, beri-beri, scurvy, pernicious anaemia, xerophthamia etc.; or they may show themselves in mild and deceptive forms that can hardly be diagnosed except by methods of the laboratory or of experimental medicine. The typical clinical forms, resulting from total specific deficiencies, are becoming more and more rare: they are limited to human groups subjected to extremely precarious nutritional conditions. As a basic knowledge of nutrition has become more widespread, the areas of beri-beri, pellagra and scurvy have become more and more restricted.

If on the one hand there has been a diminution in the incidence of typical nutritional deficiencies, diseases characteristic of the pre-scientific era when no one knew the determining factors of these evils that cut down millions and millions of lives in antiquity, during the middle ages, and even up to the past century, on the other hand there has been no reduction — under certain aspects and in certain forms there seems even to have been an increase — in the incidence of partial deficiency states and in states of nutritional unbalance that lead to various morbid conditions that are difficult to characterize, since they embrace in their pathogeny a multiplicity of specific partial deficiencies.[5]

This is one of the most tragic chapters of nutritional pathogenesis: the hidden hungers, vague in their characteristics but capable in fact of reducing the organism to a state of relative incapacity, low productivity, and lowered resistance to a whole company of other diseases that come to prey on the weakened organism.

The incidence of states of specific hunger, whether in typical forms or in forms of partial deficiency, hidden hunger, according to figures compiled by the United Nations Food and Agriculture Organization, includes and affects about two thirds of the population of the world.

Throughout this treatment of specific hungers or nutritional deficiencies, defective alimentation is the *predominating* factor of the disease. I would not want to say the *determining* factor because more and more, in the light of modern knowledge of physiopathology, the evidence indicates that derangements of health are generally due to the joint action of a number of

factors, some hereditary, others environmental in nature, some predisposing, others leading directly to the derangement in question.

The truth is that in medicine, as in the field of the social and geographic sciences, we must be more and more prudent in speaking of *determinism*. A more appropriate concept is that of *possibilism*, that is, the action of factors that make possible the appearance of certain phenomena, whether biological or social.[6] Even in this group of deficiencies where some specialists speak of a clear and indisputable correlation between the nutritional deficiency factor and the specific syndrome that this deficiency determines, we see that innumerable other factors come into play in the appearance of these morbid states. We must take account of the surprising fact, for instance, that in certain human groups with serious specific deficiencies the signs of such deficiency are rare; while in other groups with relatively superior diets, deficiency states are apparent on a grand scale.[7]

This may be explained by the notion of nutritional diseases *conditioned* or *made possible* through a biological *possibilism*. Purely theoretical recommendations are therefore very precarious, when it comes to setting the same artificial levels for various essential food elements as are recommended for different geographical areas and other human groups.

Climatic conditions, working conditions, living agents of the biotic, environment, even the psychic conditions of human groups subjected to different types of social pressures, can determine a great variability in the greater or lesser resistance of these human groups to specific alimentary deficiencies. Eating habits themselves, established over long periods and creating a sort of dynamic balance between the organism and its environment, produce great differences in the specific needs of the organism in different geographical areas, and greatly influence its ability to escape more or less accentuated specific deficiencies.

In this matter of so-called conditioned nutritional unbalance, a great deal might be said, but I will not go into details which are dealt with in the contributions by Professor Yan En-fu and Dr. Williams. Merely as an example, I would mention the important correlation between nutrition and stress, that is, the effort of adaptation that the organism makes to maintain its homeostasis in the face of difficult environmental conditions. All the factors that may interfere in this way with the digestion, absorption and utilization of nutritional principles, or that may intensify their destruction and excretion, thereby become conditioning factors of nutritional deficiency, even though the diet be adequate.[8]

Through the mechanism of the so-called antagonisms of nutritional principles, studied principally under the heading of aminoacids and vitamins by workers such as Krehl, Winje, Sure, Harper, Gessert and many others;[9] an explanation is offered for the setting up of certain deficiency states that apparently do not correspond to a real deficiency in the amounts of corresponding food principles ingested. It seems that an excess of one principle has the effect of conditioning or imposing an increase in the bio-

logical needs of other principles, and if this increase is not satisfied, a deficiency appears. Thus a diet relatively deficient in histadine becomes unbalanced when a supplementary dosage of lysine is increased; a supplement of valine intensifies a primary deficiency of treonine, and so on.

The action of certain inactivating agents is also an important factor in conditioned deficiencies. As an example, I will limit myself to citing the constitution of the syndrome of thiaminasis, which often results from the presence in the intestine of certain bacteria such as *Bacillus thiaminolitious.*[10] Victims of this condition, although eating normal amounts of vitamin B_1, show a percentage of thiamin in the blood much lower than normal, because this alimentary principle is inactivated in the intestinal tract by the inactivating bacillus of vitamin B_1.[11]

These two examples are enough. Here I merely want to stress that in view of the general facts cited, although I do not consider the nutritional factor as the exclusive *determining* factor of this group of diseases, I must nevertheless consider it as their *predominating* factor. I must also stress the fact that these states of relative deficiency have a distribution that is veritably worldwide. They attack not only the populations of the poorer and less developed regions of the world, but also populations of moderate or average development and the poorer groups of the most advanced and industrialized regions of the world.

There is a second group of diseases that prefer to attack the populations of the world's underdeveloped regions, and in whose pathogeny diet participates as a predisposing factor, an advance agent to prepare the ground. This group includes the so-called mass diseases, which fall with high rates of incidence on the undernourished and relatively deficient groups — such as tuberculosis, tracoma, leprosy, verminoses and other gastro-intestinal parasitoses. Although all these diseases have a specific pathogenic agent, their morbid manifestations, their propagation and their evolution depend greatly on the state of organic resistance of human groups, that is, on their state of nutrition. In certain cases, as in those of tuberculosis and leprosy, although knowledge is still incomplete as to the mechanism by which the nutritional factor operates and as to exactly what deficiencies of diet are most likely to predispose the organism to these ills, nevertheless it is known that a deficiency of certain essential principles, particularly aminoacids and vitamins, interfering with the mechanism of elaboration of the enzymatic systems essential to cellular activity, reduces *ipso facto* the resistance of the cells to toxic agents of all sorts. In the discussion of the nutritional factor in the struggle against tuberculosis, we will analyse this subject further.

In other cases, as in ancylostomiasis and schistosomiosis, we find that the clinical syndrome reflects a deficiency state rather than a toxic or despoiling parasitosis, since simple parasitic infestation in individuals that are well nourished produces hardly any morbid symptoms of importance.[12] As we study this group of mass diseases, we must stress the importance of this

more modern knowledge of nutrition and formulate a new preventive medicine for these evils: the attack on them through processes of nonspecific prophylaxis, that is, by increasing organic resistance through the use of good diet; by correcting the more serious dietary deficiencies and by removing their more striking anomalies.

There is still another chapter of pathology in which the influence of the food factor has been unequivocally demonstrated: that of the degenerative diseases. While the other two groups of diseases so far analysed attack underdeveloped human groups and populations, the poor and the hungry, the degenerative diseases show the highest incidence in the regions with a higher standard of living, in the well developed and industrialized areas of the world, where nutritional conditions are apparently good. Although other groups of diseases are quantitatively more widely disseminated than the degenerative diseases, there are various reasons why the nutritionists should be concentrating with such interest at the moment, in finding out the mechanism by which diet influences the appearance of the degenerative diseases, particularly arteriosclerosis and degenerative heart diseases, whose incidence in certain regions of the world, far from diminishing, seems to be on the increase.

On this point, it is sufficient to note what is happening in the United States of America. In that country, as in other that are well developed, there has been an enormous drop in mortality from infectious diseases and from nutritional deficiencies, thanks to the use of antibiotics and other chemotherapeutic products and thanks to an improvement in the dietary conditions of the people. The fact is, nevertheless, that average length of life has not increased significantly because of the continuing high mortality index from degenerative diseases, particularly cardio-renal ills.[13]

Thus the mortality for the age group of men of 55, according to data from Ancel Keys, which was 21·8 in 1925, was 19·4 in 1950 — a truly insignificant reduction. This depressing result is due to the fact that in this period heart diseases rose from 4·5 to 8·6 in the same age group. So it can be seen that a higher mortality rate for degenerative diseases cannot be attributed to the fact that length of life is greater in the well developed countries. This is still further confirmed by observations such as those made by Aschoff during the first World War, and by other more recent studies carried out by American pathologists on soldiers killed in Korea, both of which demonstrate the existence of these degenerative diseases even in young individuals. There is also the fact that man is the only animal in which arteriosclerosis occurs spontaneously, which seems to suggest that something serious has happened in the behaviour of this animal, something that has provoked this grave metabolic disequilibrium that appears in the form of arteriosclerosis.[14]

Through modern biochemical studies it has been found that a series of alterations takes place, particularly in the field of lipoid metabolism; also, that it is possible to induce arteriosclerotic changes in rabbits and chickens

by means of a diet excessive in cholesterol. All of this indicates the great influence that the food factor must have in causing this disease; the use of an unbalanced diet, excessive as regards certain components.

A certain correlation was established some time ago between obesity induced by alimentary excesses and degenerative heart diseases. Unfortunately, in spite of a whole series of studies carried out by the most reliable centres of experimental research, in spite of the investigations made on all sides, we have not yet today any clear idea of the mechanism of correlation between nutritional disturbances and arteriosclerosis, as may be seen from the report of the Symposium held in 1956, in Minneapolis, U.S.A. under the direction of the United States physiologist Ancel Keys, one of the leading workers in this field of study.

There has not even been any clear and categorical confirmation of a correlation between levels of cholesterolemia and the incidence or severity of arteriosclerotic lesions. The conclusion has been reached that no correlation exists between the absolute concentration of cholesterol in the plasma and the severity of the lesions, even in experimental animals. The phenomenon seems rather to depend on the association of these lipoids with the proteins of the plasma. Thanks to the study of Barr,[15] it was found that in animals developing ateroma the distribution of cholesterol between the alpha-lipo-proteins and the beta-lipo-proteins is similar to that existing normally in man, and differs greatly from the distribution found in the control animals. In both rabbits and dogs with ateroma the greater part of the plasmatic cholesterol appears associated with the beta-lipo-proteins, an inversion of the situation existing in normal animals.

This goes some way to show that the metabolic change that is the basis of arteriosclerosis depends not only on fat metabolism, but also on protein metabolism.

It is therefore seen that in spite of the obscure points, a bright white light is projected in the field of nutrition, revealing the undeniable fact that the types of diet used in the well developed countries are a long way from ideal.

In an interesting study published in *Nutrition Review*, Erschoff had already asked what an ideal diet might be. The following words are his: "*What is an ideal diet? Can this question be answered without a clearly formulated philosophy as to what we wish to accomplish with our own life and that of future generations? Is the 'ideal' diet one that promotes the most rapid growth, or longest survival, or greatest freedom from diseases, or the greatest capacity to survive unfavourable environmental conditions, or exposure to radiation? Is the 'ideal' diet one that best promotes fertility or mental development and productivity or is most effective in maintaining physical exertion or emotional stability? We have no assurance that these objectives are compatible. On the contrary there is good evidence that at least some of them are not*".[16]

It is further seen that these types of diet are inducing a serious metabolic upset that is becoming one of the most serious evils to assail the most highly

developed part of humanity in our days. There is a grave danger that must be pointed out. It is that in the name of science, nutritional patterns of the richer regions, considered arbitrarily as ideal, are being implanted among underdeveloped populations, where degenerative diseases are much more rare. The danger is that the areas of degenerative diseases may thus be spread throughout the world. This is one of the great responsibilities of men of science at the present moment: they must be careful about prescribing certain teachings that do not yet have a sufficiently solid scientific base. Thus they may prevent, in the field of nutrition, what has happened in the past as regards clothing, housing and work customs through the precepts of a hardly scientific hygiene which imposed on the primitive populations of the world a way of life which, far from improving their health conditions, almost wiped them out completely.

A concentration of forces is required, then, to clarify this question of the degenerative diseases. Once a majority of the infectious-contagious diseases have been controlled and the states of deficiency and hunger in the underdeveloped regions removed by means of appropriate economic development, we must still find out how to act to give efficient battle to the degenerative diseases, which day by day are becoming the principal cause of death among the world's best developed populations.

I have set forth in summary form some of the aspects that seem most significant as regards the influence of diet on group health. On this basis plans of world food policy might be drawn up which, if established on a rational and scientific basis, could lead to the elevation of present health levels. It will thereby be possible to promote a social and economic development of the world that is more balanced and harmonious, and that could well lead to an era of true peace and prosperity for all humanity.

In the various articles that make up this volume on the problem of Hunger and Food many aspects of the question will be taken up, together with their relations with other pertinent problems, so as to give an idea of their combined bio-social reality.

Lord Boyd Orr, holder of the Nobel Peace Prize and the first Director General of the FAO, shows in a clear and objective article all the significance of the contribution of science in the formation of modern society, as well as the great hopes that should be placed in the rational application of scientific achievements for the well-being of humanity.

In a cold and impartial analysis, Professorr Th. Roemer then shows how the problems resulting from the classical Mathusian biomial — food and population — should be viewed in the light of present-day scientific knowledge. Professor Michel Cépède, of the Institut Agronomique de Paris, undertakes the analysis of the economic aspects of the world food situation, emphasizing the urgent necessity to formulate a new economic approach capable of providing mankind with the food resources necessary for a healthy and balanced life.

One of the fundamental problems of the food sciences has to do with

the relations between man and the soil; this is very effectively taken up by the North American Professor Firman E. Bear of Rutgers University. His work makes clear the importance of the health of the soil for the health of human groups, and the necessity of a more effective policy for protecting natural resources for the benefit of future generations.

Professor René Dumont, also of the Institut Agronomique de Paris and author of universally acclaimed books on agricultural problems, writes on the application of modern agricultural techniques in the struggle against hunger. After analysing how agriculture transforms and makes artificial the natural environment, he writes of the immense possibilities, as well as of the tremendous requirements, of modern agriculture. His article, which is a kind of brief code of behaviour for the farmer, also recommends measures for renewing fertility and meticulous prudence in managing the natural wealth of the soil.

With a broad humanistic view of world nutritional problems, M. J. M. Gatheron, author of one of the most lucid essays on the drama of universal hunger, entitled "Le Pain et l'Or", makes a contribution of inestimable value on a subject that is much discussed and almost always distorted by political implication — the problem of agrarian structure.

Chinese scientist, Professor Yang En-fu of Peking University, presents a report on the present levels of nutrition of the Chinese people, with their cereal-based diets.

Dr. Cicely D. Williams of London presents clearly and concisely the principal effects of unbalanced diets on the nutrition of human groups.

The Director of the Institute of Human Nutrition of Prague, Dr. J. Mašek, has taken up the problem of hunger as a cause of disease, analysing the problem in the light of universal knowledge and of his own personal experience in a country with socialist economic structure.

The Argentine tuberculosis specialist Dr. Epifanio Palermo offers a documentary study of the correlations that can be shown in his country between nutritional levels and the incidence of tuberculosis, confirming our statement that hunger and malnutrition are factors of great importance in the appearance and evolution of the so-called mass diseases.

Closing this symposium, in which the problem of alimentation and hunger is studied by distinguished specialists, we present a work of the Soviet Professors A. L. Kursanov and A. A. Nichiporovich on the problem of photosynthesis, whose secret has continued until today to defy the astuteness of scientists, and upon which, in the final analysis, all human life depends. These two scientists from the Institute of Plant Physiology of the Academy of Sciences of the U.S.S.R. stress the scientific efforts that are being made to achieve artificial photosynthesis, as a practical way of bringing abundance to our famished world.

With the presentation of these articles it cannot be said that any definitive conclusion has been reached. However, we believe that careful thought on the themes analysed here will greatly facilitate the understanding of this

extremely vast and complex problem. We trust our symposium will be useful to all those who wish in some way to participate in this universal crusade which is inescapable in view of the circumstances presented — that is, in the universal crusade of struggle against hunger.

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THE IMPACT OF SCIENCE ON HUMAN SOCIETY

by

Lord Boyd Orr, Scotland

The tremendous new forces which science has let loose have shaken the structure of human society to its foundations with the result that we are living in a rapidly changing world. Some think that the change is for the worse, that the nineteenth century was the golden age of our civilization, which is now doomed. Others believe that the convulsive changes now taking place are the birth pangs of a wonderful new age in which the human family will rise to a higher level of physical and cultural wellbeing than the most optimistic social reformer of the last century thought possible.

While even the wisest cannot foresee the outcome of the present transitional phase, we can consider the nature of the changes and speculate on how the new powers which are causing the changes could be harnessed to serve mankind.

The hydrogen bomb — freedom from war

A revolutionary political change has been brought about by the H-bomb. Since the beginning of recorded history nations settled their conflicting interests by war or by "negotiating from strength" which enabled the more powerful to dominate the weaker without fighting. Now the two most powerful nations have H-bombs and a war in which these were used would involve mutual annihilation. Some Americans blamed Western European nations for "dragging their feet" in rearmament. The people of all European nations were "dragging their feet" because they feared that in a war between East and West, Europe would be the centre of the spreading death and destruction and they were not prepared to die or make the world safer for either Communism or Capitalism. Now these instruments of death can be delivered across the Atlantic. In a recent civil defence exercise in the United States it was estimated that if it had really been the outbreak of war many millions would have been killed and many cities blasted. The people of America are now inclined to "drag their feet" as also are the people of the U.S.S.R. who suffered more in the last war than any other country except Poland.

While the fear of massive reprisal with the H-bomb is the immediate deterrent to war, the permanent deterrent may be the aeroplane. Rapidly increasing numbers of people are now visiting foreign countries in a two way traffic, even between countries engaged in the present "cold war" and are finding out that the people in the countries they visit are decent people like themselves, with the same interests, the same hopes and fears. This realization of the common people of the world will make it increasingly difficult

for any government, however war-minded, to get its people to go to war. Governments now realize that war or the threat of war can no longer be used as the last instrument of diplomacy. Even negotiating from strength begins to look silly because no nation can use its strength without itself being destroyed by massive retaliation. They now see the truth of Alfred Nobel's prophecy, that science would produce such powerful weapons that a major war would be impossible without the complete destruction of our civilization. Hence they are now talking of peaceful co-existence. The cold war is now thawing. The virulent propaganda of fear and hate to foment a war neurosis is beginning to be replaced by occasional compliments. Holland has recently sent to the U.S.S.R. the gift of a great quantity of flowers and thousands of tulip and hyacinth bulbs for Moscow's public parks. The H-bomb, by making a successful major war impossible, will put an end to power politics.

The struggle for world supremacy will be replaced by the co-operation of nations for their mutual benefit under some sort of world government with an effective Court of Justice and a World Police Force to enforce its decision. This will enable nations to reduce the crushing burden of armaments now costing the people of the world 120 000 million dollars a year. This change is difficult and will take time because it involves an entirely new conception of the role of politics and is resisted by men trained in the old diplomacy. But the new era of international co-operation has already dawned. Though the League of Nations — hailed with hope by the people of the world — was killed by the old diplomacy, it had to be replaced by the United Nations which is a better organization because it has specialized agencies through which all nations can co-operate to get modern science appied to the promotion of the welfare of all mankind. Let us consider what the co-operation of all nations for this great objective could accomplish.

Modern technology — freedom from want

The advance of science and technology which enabled man to produce the H- bomb has also enabled him to produce an abundance of everything he needs for a full life. In the United States and Canada which were outside the battle area the pre-war industrial potential was doubled during the war when there was a remunerative market for all that could be produced. European nations have repaired their war damage and are now increasing production as fast as the United States. Their production is now already 60 per cent above the pre-war level. The power to produce is so great that, in spite of the destruction of the last war and the fact that since the war a large part of the industrial potential has been devoted to armaments, the standard of living in the industrialized countries is bigger than before the war. In the United Kingdom, though more than a third of the national revenue is being devoted to preparation for war, the Chancellor of the Ex-

chequer has predicted that the standard of living will be doubled in the next twenty-five years.

The use of the power-driven machine to replace human and animal muscle and increase output per man is no longer confined almost exclusively to Western Europe where the industrial mechanical revolution began, and in North America, owing to the shortage of labour in proportion to the resources of a vast continent, its development has been most rapid. Countries which were formerly content to be primary producers supplying the rich industrialized countries of Western Europe with raw material are now bent on enjoying the fruits of industrialization and even food deficit countries are sacrificing agriculture to industry as England did in the nineteenth century. The industrial potential of the U.S.S.R. is now thought by some to be nearly equal to that of the whole of Western Europe. Last year in New Zealand manufacturing industry contributed £ 2 700 000 more to the national income than farming.

Industrialization is also taking place in Australia and Argentina, and China, India and Pakistan now have similar ambitious five-year development plans which in most cases are reaching their targets. There is no reason to suppose that China, India and Pakistan which have won their freedom will not be able to develop their industries as rapidly as did Japan which, until its defeat in the last war, was never conquered and controlled by one of the Western Powers. In that case, with the industrial capacity of these countries with their huge population added to that of Western countries, the total world power to produce goods will, in the near future, be enormous.

There is now almost no practical limit to the power to produce real wealth. In the last resort rate of production depends on energy. It was the energy of coal and the steam engine that led to the industrial revolution of the nineteenth century. Supplementing coal with petroleum, and the internal combustion engine led to a further rapid increase in the beginning of the present century. Now atomic energy is beginning to be used and research is being done in the United States and India and elsewhere on the direct use of solar energy. Even with the sources of energy and other means we already have, it is possible to produce clothing, housing, clean water supplies and other sanitary measures to meet the needs of all mankind for a decent life. Hence the advance of science, in addition to bringing freedom from war, has made it physically possible for our generation to pass from a world of scarcity with resulting poverty for the majority of mankind, to one of abundance with plenty for every member of the human family. As is noted below this applies also to food.

With freedom from want, mankind can also get freedom from excessive work. Increasing output per man hour is reducing the number of hours needed for work. One of the American labour leaders has estimated that, when the introduction of electronic control to the motor car industry is completed, the number of men needed to maintain the present output may be reduced from 1 000 000 to 200 000. Not the least of the difficulties in the

transition to the new atomic age will be the adjustment of our way of life to enable people to use leisure wisely for intellectual and cultural development. It will not be easy to get rid of the nineteenth century idea that work *per se* is a virtue. Some work is necessary and is a valuable discipline for the young who should be compelled to work until they have produced wealth equivalent to the value of a lifetime's supply of the primary necessities of life. With modern machinery that should take only a few years, after which they could enjoy leisure or do more work for luxuries.

The Greeks despised manual work as fit only for slaves, and in their leisure rose to the highest level of culture. Now the machine can be the slave to serve the common people who should be able to enjoy increasing leisure. From such a vast reservoir of latent talent and genius set free human society could rise to a higher level of cultural and spiritual wellbeing than has yet been attained even in the most privileged nations. That, however, lies in the distant future. It involves a new sense of values and the direction of education to a new objective. It is easier to make machines than to adjust ideas to the machine age.

Modern medicine — freedom from disease

The advance in biological science, though not so spectacular and noisy in its results as physical science, with its wireless, aeroplanes and bombs, will in the long run bring about almost as big a change in human society. The biggest change, in the meantime, is being brought about by the advance in medicine. It is now physically possible to control and reduce to vanishing point nearly all infectious and contagious diseases. In countries like the United Kingdom, where the new knowledge of preventive medicine began to be systematically applied in the later half of the nineteenth century, the expectation of life at birth was increased by ten years from 40 in the early part of that century to 50 in 1900. Since 1900 it has increased by another 20 years. Now the expectation of life in the United Kingdom, as in other countries where modern medicine has been applied to the elimination of disease, is about 70 years. In Asia, Africa and Latin America, with about two-thirds of the population of the world, where it is only beginning to be applied as, for example, by the elimination of malaria and the introduction of modern sanitation the fall in the death rate is so great that in some cases the population is being doubled in less than 30 years.

What number of people can the Earth support?

The rapid increase in the population of the world is rightly causing alarm. In 1800 it was increasing at the annual rate of about 4 500 000. By 1900 the rate had risen to about 11 500 000. The highest rate of increase was in the European race. In England and Wales, for example, the population increased from about 9 to over 30 millions in the nineteenth century, not counting the

millions who had emigrated to the new continents of America and Australasia. Now disease is beginning to be controlled in practically all countries, and the rate of growth of world population has risen to over 40 000 000 a year. At the present rate of increase the population of the world will rise from about 2 000 million where it was at the beginning of the last world war to about 5 000 million by the end of the present century.

Can the earth be made to provide food for such a large number? On this, opinion is divided. Food is the main limiting factor in growth of population. According to Malthus, population tends to increase faster than food production so that death from hunger for part of the population is inevitable, unless increase of population is restricted by birth control. And, indeed, there has never been sufficient food for all the people of the world. Bad harvests have always been followed by famine and death. In the Bengal famine of 1770 a third of the population (10 million) perished. About a hundred years ago, fourteen millions died in a great famine affecting both India and China. Up until the beginning of the nineteenth century famines with a heavy death roll occurred in European countries. Even in normal harvests the poorest people in all countries lacked sufficient food. It is significant that in the Lord's Prayer "*give us each day our daily bread*" takes precedence even of the petition for the forgiveness of sins.

The modern idea of what constitutes an adequate diet has led to an increase in the estimate of the world's food supply to meet the needs of the human family. Until about thirty years ago it was assumed that if people had sufficient food of any kind to satisfy hunger their needs would be met. Now it is know that in addition to calories to satisfy hunger the diet must contain sufficient protein, vitamins and minerals to maintain health. Dietary surveys in the 1930s showed that the average diet of the poorest third of the population in the United States and the United Kingdom was deficient in one or more of these constituents with resulting ill health, especially in mothers and children.

Since then, owing to social measures such as cheap milk and school meals for children, and the rise in the standard of living which enables the poorest part of the community to buy the more expensive protein and vitamin-rich foods together with a better appreciation of the kind of diet needed for health, gross forms of malnutrition have almost completely disappeared. But, while the food position has improved in the industrialized countries, two thirds of the world's population still suffer physical defects and diseases due to lack of an adequate diet.

More food is needed to bring people up to this higher level of nutrition than merely to satisfy hunger which was the old standard of requirements. In 1946 it was estimated that, in view of the anticipated increase in population, world food production would need to be doubled in the next twenty five years to provide an adequate diet for all the people in the world. From 1946 to 1950 the population of the world increased faster than food production. Since then, owing to good harvests in the last four years, and agri-

cultural development, food production has caught up with population. The present position however is not much better than in pre-war days when two thirds of the population of the world suffered from malnutrition. Since then, owing to good harvests in the last four years, and agricultural development, food production has caught up with population. The present position however is not much better than in prewar days when two thirds of the population of the world suffered from malnutrition. Since then, excluding the communist countries, food production has increased a little over 25 per cent while population has increased also by nearly 25 per cent. But the biggest increase in food production is in North America and Western Europe where people are now better fed than before the war. In North America there is a great unsaleable surplus. The position begins to be like that of the 1930s, too much food in some areas threatening the standard of living of farmers, and in other areas too little food affecting the health of the people. In a well ordered world these two evils would cancel each other out. The food supply can be taken as a good index of the wealth of different countries. Lack of food is the best index of poverty.

Some think it will never be possible to provide sufficient food for all the people in the world because birth control will never be applied sufficiently to stop the growth of population, and also because of the continued loss of fertile land by soil erosion owing to the pressure of population on the land. On the other hand, others believe that, as the standard of living and education rises, the birth rate will fall as has happened in Western Europe. But in the United States, the wealthiest country in the world, there has been a baby boom in the last few years. This however may be only an exaggeration of the usual post-war increased birth rate. It is impossible to predict at what rate or how long the world population will continue to grow. It seems probable however that the death rate will continue to fall for a long time without the birth rate falling to the replacement level, and the population may grow to twice or even three times its present size in the next hundred years, though one may at least hope that before that time it will have become stable or even begun to decline.

With modern agricultural and engineering science it is physically possible to produce sufficient food for two or three times the present population. It is reckoned that, if in every country, all farming were brought up to the level reached by the most efficient farms the present world food supply would be doubled. Thus for example, in United States, the yield of wheat per acre is only about half that got in some Western European countries with more intensive methods including adequate use of fertilizers and control of weeds and plant disease. In India, the Japanese method of rice cultivation has doubled the yield per acre, where it has been applied. Even in countries with the most efficient agriculture the yield per acre and per animal is increasing faster than the increase in population.

Soil erosion and destruction by flooding of rivers is a menace but, with modern engineering, fertility can be restored to the ruined lands and the

destructive power of floods harnessed to yield hydro-electric power and the water for irrigation, as indeed is being done in several countries. The only practical limit to food production is the amount capital governments are prepared to devote to it. The age-long food scarcity with periodic famine can be made to give way to a new age of abundance of food for everybody. This could be done within a few decades if governments were prepared to co-operate on a world food plan, and to devote to world food production half the efforts being devoted to preparation for war.

The revolt of the subject races — freedom from oppression

Apart from the H-bomb which deters any of the great powers from embarking on another war, the most important political change in our time is the revolt of the subject races. The white man has got notice to quit. Empires are in process of liquidation. The fundamental causes of the revolt is the poverty of the common people who now realize that their poverty is unnecessary and attribute it to their foreign rulers. They are determined to take control of their countries and to develop their natural resources for their own benefit. The large countries, especially China and India which have thousands of university graduates educated in America or Europe and their own research institutions, should be able to apply modern technology to industrial development as rapidly as Japan, which, free from foreign rule, within forty years became one of the great industrial and military world powers. In that case during the lifetime of our children the white man's supremacy in the world may be challenged by the coloured races.

The Afro-Asian Conference of Bandung representing more than half the population of the world arranged by men, who a few years ago would not have been allowed in a white man's club in Asia or Africa, may be a portent of the shift of the centre of world power. As General Smuts predicted, the upsurge of Asia which began the revolt of the subject races is by far the most important political event of our time. Compared with it, European politics are of minor importance. The industrialized and at present powerful western nations can co-operate as political equals with these once subject nations in developing the resources of the earth for the benefit of the whole human family. Otherwise, without the help of the West, they may develop their industrial and military power in hostility to the western civilizations.

The birth of a new world order

We have argued that the H-bomb and tourist traffic will put an end to major wars, that the advance of technology will change a world of scarcity into a world of plenty, and that colonization will be replaced by the political independence of all nations with a world government able to keep the peace and facilitate the co-operation of all nations in international affairs.

Thus, under the impact of modern science, human society is moving

towards the "New and Better World" promised by the late President Roosevelt, a world with the political and economic freedom for all men in all lands promised in the Atlantic Charter.

The movement to this better world order is opposed, as every forward movement has been opposed, by some who have a vested interest in the old order which is passing. The rate of progress depends upn the enlightenment of the people to enable them to realize that science has brought within our reach a society free from the intolerable evils of war, hunger, disease and poverty. This edition of *Science and Mankind* should be a valuable addition to the already extensive literature promoting a well-informed world-wide public opinion necessary for the rapid building of the new world of peace and plenty which seems the inevitable outcome of the great events of our time.

DOES THE THEORY ENUNCIATED BY ROBERT MALTHUS IN 1798—1805 CORRESPOND WITH THE REALITIES OF THE SECOND HALF OF THE 20th CENTURY?

By the late

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Enunciating the theory that a population increases faster than the production of its means of existence, Thomas Robert Malthus (1798—1805) stated as follows: "*As far as our experience goes, a population tends to expand beyond the limits set by the means of existence provided by any given economic and social organization*".

He also expressed the opinion that a population increases by geometric progression (1, 2, 4, 8, 16), while the production of food increases only in arithmetic proportion (1, 2, 3, 4, 5), and there are competent economists who regard this as "*the most infrangible and important law in political economy*".

In the 150 years which have passed since Malthus enunciated this theory his prediction has not come true, and therefore the question selected for the subject of this contribution may cause some surprise, since for the last fifty years eminent experts (such as Aerobos, of Berlin; East, of Columbia University, U.S.A.; Knibbe, of Australia; Czuber of Vienna; and many others) have written innumerable papers of the development, past and future, of the figures of population and of the production on its means of existence. The specialist opinions were divided; some (East and Knibbe) maintained that this theory is correct, while others pointed out that the predictions have not proved correct and never would do.

New reasons are provided for the consideration of this question at the present time, however, by the four following facts:

1. Since the birth of Justus von Liebig some 150 years ago, there has been a fundamental change in agriculture due to his life work and the work of his pupils.

2. The fact that we now have 50 years of careful research work on which we can look back, provides us with reliable indications, formerly lacking, of the possibilities of increasing the yield of the fields and stables in the future.

3. According to the Food and Agriculture Organization of the United Nations (F.A.O.), half of mankind, mostly in Asia, with less than 2 250 calories a day, is undernourished, and is thereby restricted in its productive capacity. Lasting peace in the world, for which we all long, cannot be secured if so large a proportion of the population is suffering from hunger.

4. Since 1945 a certain number of publications have appeared,* mainly in the Anglo-American part of the world, raising the question again, and in most cases arriving at a theoretical conclusion similar to that of Malthus.

In 1898, exactly a hundred years after Malthus, the President of the British Association for the Advancement of Science, Sir William Crookes, gave a lecture on "The Problem of Corn", in which, basing himself on the fact that by 1930 all the arable land in the world would be under cultivation, he foretold that from then on the world would suffer from famine. Fifty years later, in 1948, Lord Boyd Orr, Director General of F.A.O., who was awarded the Nobel Peace Prize a year later, said much the same thing, as follows:

"*In the race between population and food production, population will win. If we do not take prompt steps to win that race, we shall find ourselves faced with far-eaching catastrophe*". A year later, in 1949, the American Dr. Salter wrote: "*Any hope of escape from famine is bound to be buried under an avalanche of population*".

Just as, in 1898, Lawes and Gilbert, of Rothamsted, refuted Crookes' alarming prophesies, so at Rothamsted again, in 1948, Sir John Russell refuted that of Lord Boyd Orr, and my object here is to state a view, from the German angle, on this problem, which is causing anxiety all over the world.

I will start off by remarking that security of tenure of the places where one works and where one lives is as important as the securing of food. Without the former, the latter is valueless.

Malthus' forecast has not come true in the 150 years since he made it, although the world's population has increased from 500 million, in 1700, to 775 million, in 1800, 1 567 million, in 1900, and 2 300 million, in 1950. Whereas Malthus, working on the material at his disposal, reckoned on a doubling of the population every 25 years, in actual fact there have been times when it has taken 100 years for it to double. On the other hand, it has been possible to place at the disposal of this growing world population more and more food, of better quality. Not only has the number of calories a day been increased, but there has also been a considerable replacement of vegetable, by animal products.

In Germany, for example, the consumption of breadmaking grain per head per annum decreased from 300 kg in 1800, to 200 kg in 1900, and

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* Pearson and Harper: *Hunger in the World* 1945
Shephard: *Food or Famine?* 1945
Digby: *Food Tomorrow* 1946
De Turk: *Deliverance from Famine* 1948
Metternich: *The Desert Threatens. The Foods Basis of the Human Community is Compromised* 1947
Voigt: *The Road of the Survivors* 1949
Sir John Russell: *Food and the People* 1949

to 97 kg in 1949 after rationing was stopped, while the consumption of meat increased from 29 kg in 1880, to 54 kg in 1913, and that of butter 6·8 kg in 1913, to 8·5 kg in 1948. It has been found, in the course of experimental feeding, that for each animal calorie produced, 5 vegetable calories are consumed, but in practice, owing to mistakes in feeding, losses in breeding, sickness and pests, the latter figue is 7, or even 10, according to an estimate arrived at by Sir John Russell, for many years Director of the great English agricultural experimental station of Rothamsted. If the world population as a whole were consuming animal calories on the same scale as that of the U.S.A., it would not be 2 300 million people, but only 1 000 million, who could live on the world's present production. But, on the other hand, if it were to do so on the same scale as the yellow races, the world's present production would provide for another 500 million, i. e. for a population of 2 800 million.

The present world population is increasing annually by about 20 million, or by 0·85 per cent. What this means will be appreciated if one reckons that, at the end of each hour of the day and night, there are 2 400 more human hearts beating than when that hour began. One cannot predict with certainty whether this rate of increase will be maintained in the future, and if so, for how long, but there are some indications that it will slowly diminish. The principal cause of this would appear to be the fact medicine is prolonging life so much that almost one household in three has to house, feed and clothe one or two close relatives of the preceding generation. As the result of this there is a reduction not only of the will, but also of the material means, for the rearing and education of children.

The situation is developing very differently in different countries. In Holland, for example, the population has increased from 5 to 10 million since 1900, which means that it has doubled in 50 instead of in 100 years. In Germany, on the other hand, a considerable part of the increase of population is due to the fact that the average expectation of life went up from 34 years in 1870, to 61 years in 1935, which means of course an overloading with people who can no longer work. Such 'ageing' of the population bears particularly hard on those peoples which participated in the first and second world wars, and which now, as the result of their enormous losses in the more productive age-groups, have a senile structure which is quite pathological. It is estimated by the statisticians that in Great Britain and France the population will be reduced by as much as 4 million by 1970 on this account, while in Germany, war losses estimated at 10—11 million are expected to cause a reduction of population of about 1 million in five years, even if there is no large-scale emigration to increase that figure.

In the statistics for the years 1943/44 worked out at Geneva by Notestein and his collaborators, the development of the population was estimated as follows:

	North-West and Central Europe	Southern and Eastern Europe	Russia
	(in millions)		
1940	234	165	174
1950	237	177	203
1960	234	187	228
1970	225	192	251

The proportion between North-West and Central Europe, on the one hand, and Southern and Eastern Europe plus Russia, on the other, is thus expected to change from 1:1·5 in 1940 to 1:2 in 1970, after which the tendency will continue in the same direction.

It is difficult to calculate the population figures for various countries and continents, as past predictions of population have not proved correct, and because those now being made differ from each other enormously and are often fantastically contradictory. A recent example of this occurred in 1948, when Gustave Stolper wrote in *Fortune:*

"Germany has become a nation of women and old people. The time is already in sight when the united population of the four Zones will be reduced to that of France — 44 million. The future population of Germany lies buried in the ruins of world war II".

For at that very same time the French population statistician, Paul Henry, was writing:

"Despite the loss of a quarter of the territory of the old Reich of 1920—1939, Germany, thanks to the entry of German refugees from the East, will soon have again a population of 70 million, and, in spite of the enormous excess of women and of the ageing of the mass of the population, this will increase beyond 70 million because the vitality of the people is unchanged".

What influences future population figures can be only roughly deduced from the facts of the past. We must, therefore, for all that may be argued against it, take as the starting point for our estimation the assumption that the population will go on increasing at a rate of 0·85 per cent. per annum, i. e. by 20 million, though in some countries the increase will be faster, and in others slower, than the average. The factor which will really determine whether that figure is accurate is the degree in which it will be found possible to increase, if at all, the average expectation of life in Asia, which in India is now only 27 years.

All kinds of politicians, statisticians and geographers have tried to calculate the world's maximum capacity for human population, and have arrived at figures varying between 5 000 and 8 000 million. These figures show that the world's present population is still not half, and may be only a quarter, of that which it could support, given only the productive technique of today.

With such figures before one, one wonders how it was that Malthus and his contemporaries could have built up the theory now known as Malthusianism, for it should be borne in mind that it was only 50 years after Malthus that Justus von Liebig laid the foundations of the science of maintaining and increasing the fertility of the soil and of increasing its yield per hectare. Liebig was the first to teach us that a system based on farm manure only does not provide for the complete restitution of the elements drawn from the soil, but that the nutritive elements exported from a farm each year must be balanced by the purchase of inorganic fertilizers, and that any other policy entails robbing the soil in a way which will, sooner or later, reduce its fertility. It was he, therefore, who, a hundred years ago, provided the preliminary data, which are of decisive importance, for the development of the production of mineral fertilizers, for Europe to begin with, but later for the whole world.

Next came, in 1888, the epoch-making discovery by Hellriegel of the utilization of atmospheric nitrogen by bacteria in the soil which live in symbiosis with leguminous plants, followed by the even more important discovery by Haber-Bosch-Mittasch of the process for the production of synthetic nitrogen fertilizers. The combined effect of these discoveries was the doubling of the yield per hectare in 66 years, and it is now known for certain that 50 per cent. of the increases of yield achieved over the past century are due to the restoration to the soil of its nitrogen content by means of mineral and synthetic fertilizers.

A further fact which can be proved with certainty is that 25 per cent. of the increases of yield, both of the field and of the stable, since 1900, have been achieved thanks to the development of artificial selection. In its first phase, which lasted until about 1910, this selection worked on the principle of isolation propounded by Philippe de Volmorin in Paris in 1856, but in its second phase, it has used the laws of Mendel. There are now very definite grounds for believing that by the full application of artificial selection, which amounts to the direction of evolution, and annual increase of vegetable and animal products of about 0·5 per cent, increases of 25 per cent. every 50 years, have been, and will continue to be, achieved.

This extra 25 per cent. increase of yield has been achieved by the cultivation of more productive types of crop (field vegetables, instead of cereals), by the consequent improvement of crop alternation and tillage, and by fighting diseases and weeds. The net result of it all in Germany has been proved by Woermann to have been an annual increase of the nutritive value of agricultural products of 2 per cent. over the period 1880—1920, and of 3 per cent. over the period 1920—1940, while the increase of population over those periods has been barely 1 per cent. per annum. Similarly in other countries, as scientific agriculture has been applied, so the production of foodstuffs has increased proportionally, and definitely faster than the increase of population.

Malthus made two mistakes: on the one hand, he grossly over-estimated

the increase of the population, and on the other, he was unable to foresee forthcoming developments in agricultural production. It is not surprising, therefore, that the last 150 years have proved that his theory has not the slightest confirmation in fact. It would be unfair, however, to reproach Malthus with this, for he could hardly have foreseen such developments.

Is it possible that Lord Boyd Orr is right, and that everything is different now, in the second half of the twentieth century? Must we really reach the upper limit of food production, while the population goes on increasing rapidly? This is a matter which concerns all peoples, and it can very safely be stated that even a population which continues to increase at a rate of 1 per cent. per annum, thus doubling itself every 77 years, can have sufficient means at its disposal to secure for itself food which is not merely adequate, but even better than at the present time.

Let us just examine the possibilities:

1. As in the past, so also in the future, mineral fertilization will be the lever to raise the output of foodstuffs, and to do so most quickly. Julius Kün was already using in 1880, for his experiments at Halle with continuous cultivation of rye, 40 kg of nitrate, 60 kg of phosphates, and 80 kg of potash. As compared with that, however, the figures for maximum consumption in Germany between 1936 and 1938 were only 26, 26, and 44, i. e. half those prescribed by the agricultural chemists (Maercker, Paul Wagner, and others) after the years 1880—1900. Holland is the only country where the consumption of nitrate has reached 44 kg, and there that level will soon be surpassed. If we base ourselves on the results of thousands and thousands of tests with fertilizers, carried out on hundreds of ordinary farms (not on experimental fields) we may reckon that omission to use mineral fertilizers on the scales prescribed by Kühn has led, in Germany alone, to an annual under-production equivalent to 6 million tons of cereals, or of 300 g of bread or its equivalent per head *per diem*. This lack of production is equal to 66 per cent. of the amount of cereals imported into the European continent, which averaged 9 million tons a year in 1935—1938 (Woermann).

This shows us, on the one hand, the extent to which neglect has been prevalent during the first half of the 20th century, and on the other, what are the future possibilities inherent in the farms of Germany and of Europe as a whole. We must not shut our eyes, however, to the fact that these possibilities cannot be realized unless the production of fertilizers increases on the scale required. Their realization in Germany was limited after the war by the restrictive regulations of the Occupying Powers and by lack of capital, but it will be achieved all the same in the course of some decades. What has just been written here finds confirmation in the fact that since 1936 the production of nitrate fertilizers has been increased two and a half times in England and three and a half times in the United States.

In the course of the last twenty years, the United States, Canada and Russia have increased their use of mineral fertilizers, and have changed over from monoculture to the rotation of crops. In the increased harvests

which have actually been achieved in those countries are proof of the correctness of these measures, even in the coldest countries in the world. Furthermore, experts are unanimous that the development of means whereby nitrate fertilizer can be applied slowly and regularly throughout the period of plant growth would make it possible to achieve results hitherto unknown. The development of these means is therefore the first priority for the fertilizer and agricultural chemical industry.

2. It has been mentioned above that the application of plant breeding has produced an annual increase of 0·5 per cent. There is no doubt that, if a correct policy is pursued, this will do so also in the future. There are many reasons to believe, indeed, that future developments in biological selection will produce even greater results, both in plants and in animals, as is shown by the following three examples:

a) A "hybrid maize" is the first generation of a cross between 2 or 4 strains kept pure by self-fertilization. Such a "hybrid maize" gives yields 25 per cent. greater than that of the origin species (not the self-fertilized strains). "Hybrid maizes" of this kind have spead rapidly in the "corn belt" in the United States, and there are States where already over 90 per cent. of the area sown with maize is sown with hybrids. These substantial increases of yield are the fruit of the forty years of biological research done by Shull from 1903 onwards.

b) Dutch selectors of sugar-cane have succeeded in 25 years in increasing the yield of sugar per hectare from 80 to 170 quintals, which means an annual increase of 3 per cent, or six times the 0·5 per cent. mentioned earlier. This achievement was due to the successful systematic crossing of varieties and inter-crossing of species, and to the doubling of the chromosomes, i. e. to selection of polyploids. This method is already practised generally in Europe for forage plants and rye; a rye with twice the normal number of chromosomes yields 17 per cent. more grain.

c) This is an example which demonstrates the action of biological selection in microorganisms. The mould *Penicillium* produces penicillin. My former collaborator, Dr. Thren, succeeded after two years' work in isolating strains of this mould which produce in a given time four times the basic amount of penicillin.

3. Various plant diseases reduce harvests by at least 15 per cent. in Germany, and by between 25 and 50 per cent. in the sub-tropical and tropical countries. The selection among various cultivated plants of disease- resistant varieties, though it does not eliminate such damage entirely, at least reduces considerably the losses due to it. Comparative tests over a period of ten years have shown that varieties of barley which are resistant to *Erysiphe graminis*, yield 10 to 12 per cent. more than the average for the year. Similar proofs have been secured by brilliant work by American and Canadian breeders. Thus, by the expenditure of a million dollars a year for 20 years, or of a total of 20 million dollars, 440 million dollars-worth more wheat a year has been harvested, thanks to the planting of rust-resistant wheat.

4. In the last decade an entirely new field has been opened up by biochemistry. Organic insecticides, such as the DDT preparations, benzine hexachloride, the phosphoric esters for use against animal predators, and, the hormone weed killers, are the most recent products of biological research which have already been used over many millions of acres in Canada and the United States, to increase yields by the suppression of weeds. While we are just starting on this kind of thing in Germany, the trials which we have carried out so far with fields where the weeds have been suppressed have shown increases of 22 per cent. in the yield. The existence of surprising possibilities is a fact which will be recognized not by optimists only, but by those who weigh up things calmly as well.

5. Ever since the time of Liebig efforts have been directed solely towards securing increases of yields per acre, but during the last 30 years a beginning has been made with the investigation of the equally important problem of how to reduce the losses sustained in storage, and of those suffered in silos and potato cellars (Agermin). Attention has been devoted also to the modernization of methods used for the preservation of perishable foodstuffs, by the use of organic preparations and by refrigeration, with a view to reducing the enormous losses in nutritive value of forage due to storage (Amasil, Kofasalz).

6. All this is by no means enough, however, for biology is opening up completely new ways of producing food. I have in mind here, not hydroponics, which got going in the United States during the war years, but rather the production of fats and proteins with the help of microorganisms, and by yeasts, bacteria and seaweeds. In Trinidad and Jamaica, for instance, factories have been established where the *Torula* yeasts are used to produce 5 tons of food rich in proteins daily out of molasses and useless bagasse (the by-products of the sugar-crushing mills). The prospect seems likely, moreover, that a food containing 48 per cent. of protein will be obtained from the green alga *Chlorella*.

Everything is dominated, however, by the extension of irrigation and of the area under cultivation. Out of 14 400 million hectares of dry land in the world, 7 000 million, or 48 per cent., can be used for agricultural purposes, but in actual fact, even if the cattle ranches are included, only about a half of that area is so used. In Africa, in South America, in Australia, there are still vast areas which could be used for food production if the fight aginst drought could be won, by irrigation and the artifical production of rainfall. Research carried out over many years by the Administrative Council for Agricultural Technique (K.L.T.) (Schonopp) has shown that artificially-produced rainfall produces yield-increases averaging between 30 and 35 per cent. in the range of climate over Germany alone, and would produce far greater increases in drier and warmer countries.

The development typified by the increasing use of mineral fertilizers during the first half of the 20th century will become clearer during the second half of the century through the basing of economy on water-supply.

The very great importance of this is shown by the fact, according to F.A.O., that, though only 13 per cent. of the world's surface which is under cultivation is irrigated, that area produces 25 per cent. of the world's food. The result already achieved by vast systems of water control in the Sudan, the Tennessee Valley, and elsewhere, and those which may be expected to result from the execution of the large-scale plants for Anglo-French joint development of the Volta region and Nigeria, in West Africa, and the completion of vast projects in the Volga region and in Trans-Caucasia, in Turkey, in Iran, in India and in China, afford solid grounds for optimism regarding food-production in the next half-century.

These possibilities of extending the area brought under cultivation differ, of course, from those mentioned earlier of increasing the yield per acre, in one very important respect: they call, not only for heavy capital expenditure on the construction of reservoirs and irrigation systems, but also for further heavy capital expenditure to finance the colonization of areas previously unused. The projects are so vast that they cannot be completed even in the next fifty years. The capital required for the opening up of regions which are still uninhabited is much greater than that which was required fifty years ago and than that which was actually used for increasing the harvest in regions already inhabited and in use.

The opening up and bringing under cultivation of new areas in the various continents will be done mainly by the white races, who will be called upon to provide the farmers, engineers and personnel for training, as well as the capital. All countries which are, or which may in the future become, overpopulated will thus find themselves presented not only with outlets for a considerable discharge of their surplus population, but also with great scope for their work.

The increase of yields per acre and the extension of the areas under cultivation make it definitely certain that even in the second half of the 20th century food production will increase faster than the population, provided only that reason triumphs and peace is preserved. The spectre of world famine has been banished by developments on the firm foundation of thousands of experiments based on scientific knowledge, and on thorough investigation in all kinds of fields, such as Malthus cannot have foreseen.

It would be unwise, however, to ignore the fact that these favourable prospects are liable to be thrown out by various awkward factors:

1. Cultivated soil is itself a living organism. A question which is worrying the experts is, therefore, whether it is like plants, animals and human beings, and subject to fatigue and ageing. Is the formation of arable soil out of inert rock the beginning of a process of decadence and old age? Is the fertility of the soil something which comes into being and then disappears?
2. The purely mechanical destruction of arable land by the erosive effects of rain and of the rivers, and as a result of its tillage, reduce its area. Climate

has an aggravating effect in this connexion, which must be countered by the planting of protective belts against the wind.

3. Will the law of the action of growth factors, worked out by Eitscherlich, a pupil of the University of Kiel, after 50 years experience, limit future increases of yield? According to this law, increases of yield are not obedient to a linear relation, as was believed by Malthus and Liebig, but to a logarithmic curve, with the result that each extra unit of yield calls for greater expenditure than that which preceded it, or, to use a simpler formula, that "the latest unit of production is the most expensive". This law of biology holds good for every kind of organic production, for all living beings, in every continent, for all kinds of soil and for all climatic zones. It is a fundamental law of biology. Consequently we must not expect future increases of yield per acre to bring about a reduction of the cost of the means of existence.

Ignoring, for the moment, however, all economic consequences, I will sum up as follows:

The doctrine of Malthus and his successors has not been confirmed, either in the 19th or in the 20th century, in either of the two following respects:

1. The population has not increased by a long way at the rate expected by Malthus on the basis of the facts which he had carefully collated. He expected a doubling of the population in 25 years, but in fact this took 100 years! The signs are, moreover, that it will take place even more slowly in the future. We must reckon, however, that in the year 2000 the world will have a population of about 3 000 million people.

2. Food production, on the other hand, has increased far more rapidly than Malthus could expect on the basis of the knowledge of his era. The development of agricultural chemistry after Liebig gave food production such a thrust forward that it doubled itself in 66 years, while the population was taking 100 years to do likewise. Everything goes to indicate that, in the next 50 years also, food production will increase faster than the population. The extent to which food production will increase will be determined by the development of the underdeveloped countries, which are inhabited by two-thirds of the world's population. This forecast is only, as I have indicated in my heading, up to the year 2000. It would be impossible, at the present time, to forecast beyond that.

What has been written here is not imagination as in the science fiction about the future, by Hans Dominik, which we have seen and are seeing come true in certain fields, but is solidly based on scientific knowledge derived from thousands of experiments in agriculture. This claim may be countered by quotation of the fact that in recent decades there have been shortages of food, sometimes limited and local, sometimes extending over wide areas. Two things, however, cannot be denied: firstly, the depth of unreason in Man, which works in the opposite direction to that indicated by his designaton of "*Homo sapiens*"; and, secondly, the effect of a faulty system of distribution. The crux of the problem for the future does not lie

in production, but in the balance between those territories where there are surpluses and those where there are deficiencies — between rich countries, which cannot sell their surpluses, and poor ones, which are short of food, but which have not the means to buy the surpluses available from the former. That, however, is a problem of international organization, and therefore relates to a quite different fields of human activity.

Those who doubt my conclusions will argue, of course: why, if things are as you state, is it that more has not been produced in the past? I can answer that in a few words, as follow:

Progress is slower in all fields of agriculture than in a trade, industry or science. The full exploitation, in the broadest sense, of any knowledge in the science of agriculture takes about 30 years, for the following reasons:

1. Because, in Germany alone, it must be adopted in 2·8 million farms, and in the world as a whole, in 100 million farms, with the most varied conditions as regards climate, soil and economics.

2. Because the training of the younger generation of peasants, as compared with that of other professions, is woefully backward in many countries, including Germany. The young peasant is not obliged to go to any professional school, or to acquire any certificate of proficiency, as are his counterparts in any other profession.

If agricultural production is to increase in the future, the Ministry of Science and Education, in all countries, has as much responsibility as that of Food and Agriculture. It depends on both of them:

1. That research in the vast field of agricultural science, in the widest sense, shall be not merely maintained but intensified, because the saying, "The last step in knowledge costs the most", is true here also, in a modified sense.

2. That the training of the whole of the peasantry in accordance with the advance of agricultural science shall be improved to such a degree that the peasant will understand how to apply new discoveries correctly.

The further science advances, the better must be the training of those who must ultimately apply its new discoveries. Not one peasant in every hundred, but every peasant must understand and must be able to apply the achievements of agricultural science. Agricultural science does not want only to make new discoveries; it wants to see them applied. The most important measure to ensure the feeding of a growing population is the training of the young peasant who tills the fields and feeds the cattle. Without that the achievements of agricultural science can produce no effect.

It is truer today than when it was said by Liebig 100 years ago: "*The wise man knows that no great advance is possible in our world without science*".

May our conduct, our thinking and our work be always guided by the epigram:

Salus populi suprema lex
(May the good of the people be our supreme law).

THE FOOD ECONOMY OF THE WORLD

by

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Food economy today is dominated by the fact that two-thirds of the world's population is undernourished, at a time when there is talk of food surpluses and of agricultural "over-production". That this fact, observed during the crisis of the 1930's, was no accident, has been proved since then by the way in which surpluses appeared again immediately post-war reparation of damage done during the second World War made it possible to raise the world's agricultural production per head of population to the levels prevalent during the years 1934-38, and are now seriously worrying producers.

It is not technical difficulties which are acting as a brake on agricultural production, and which seem likely to prevent it from achieving its 1960 targets, as set for it by F.A.O. in 1946,[1-2] so much as a set of "economic" conditions — the same set as is responsible for the existence of undernourishment in a period of so-called "over-production", of poverty in the midst of abundance, indeed of poverty due to abundance.

* * *

In order to analyse this situation, we must begin by deciding on some unit of measurement which is not affected by fluctuations of prices, and which gives a fair idea of actual production, such as the level of food values. We might take, as a first approximation, the vegetable, or original, calorie, which has been used to make estimates of food production, in order to take into account the fact that animal products (milk, meat, eggs etc.) result from the transformation of vegetable products consumed by animals. This transformation is extremely inefficient, as is shown by the fact that it is estimated that an animal must consume, on an average, 7 vegetable calories to produce 1 calorie of human food.[1] Where, however, the vegetable diet is improved in quality as well as in quantity, the production of animal calories is correspondingly increased[3].

If the diet, measured in ultimate calories, hardly varies from once to twice between famine and plenty, in vegetable calories, the situation is quite different. In the world-wide enquiry into nutrition carried out in 1934-38 at the request of the League of Nations, the results of which were published by F.A.O. in 1946[1], the extremes, in terms of ultimate calories, are Korea and New Zealand, the Koreans consuming 1 940 calories a day, and the New Zealanders, 3 280, a difference as of 1 to 1·7, which would seem to confirm the old adage that "a man cannot have two stomachs".

In the daily diet of the average Korean, however, there are 1 793 calories of vegetable products and only 111 calories of animal products, whereas in that of the average New Zealander these figures are 2 254, and 1 027 calories, respectively. This means that the diet of these two peoples is the following:

Korea : 1 793 + (111)7 = 2 570 vegetable calories
New Zealand: 2 254 + (1 027)7 = 9 443 vegetable calories

This shows a ratio of a little under 4:1, but if a comparison is made between some other extreme cases, not in final, but in vegetable calories, the figure may well be surpassed, that for Java and New Zealand, for instance, being nearly 4:5. In other words, it required 4 times as much agricultural produce to feed a New Zealander in 1934—38, as to feed a Korean or a Javanese.

If the concrete facts are expressed in vegetable calories, they show that food consumption is not as inelastic as "economists" have hitherto pretended. As the health level is very closely related to that of nutrition, expressed in vegetable calories, the latter may be taken as a reliable criterion by which to measure both the production and the consumption of food[3].

* * *

An "economic" system should, on the one hand, promote the production required for the satisfaction of the needs of the world, and on the other, render possible the exchanges whereby products may be distributed in such a way as to satisfy as well as possible the world's varying needs. In relation to "the first freedom; freedom to eat"[3], it should be noted that on the eve of the second World War neither of the ends just stated was being satisfactorily achieved.

Taking the world as a whole, if its 2 500 million people had all been fed on the same scale as the Danes, food production would have covered only about:

31 per cent. of the world's needs in cereals and fats
29 per cent. of the world's needs in fish
28 per cent. of the world's needs in milk
26 per cent. of the world's needs in potatoes and cocoa
21 per cent. of the world's needs in sugar
and 9 per cent. of the world's needs in meat[3]

Aiming lower, F.A.O. estimated in 1946 that the increase of agricultural production necessary and possible between 1937 and 1960 would be:

21 per cent for cereals
27 per cent for roots and tubers
12 per cent for sugar
34 per cent for fats and oils

80 per cent for dry vegetables
163 per cent for fruit and green vegetables
46 per cent for meat
100 per cent for milk[1]

The world's agricultural production will, in fact, be doubled.

It is well known, however, that even these limited targets will not be achieved at the present rate of progress, and that the index figure for 1960/61 will be barely 140, instead of 200,[2] for there are already places where prices are tending to fall seriously — world prices for cereals, sugar, fats and milk products are falling to levels which make it impossible to export at prices acceptable to the producers. If it were not for measures taken by various governments, and notably by that if the United States, to keep up the prices paid to producers, the agricultural production of the world would be tending to recede, when it should be continuing to expand.

What can be said, next, about the distribution of production, and of the food made available by international trade? Will the principle that the pursuit of private profits assures the most useful distribution of wealth be proved wrong, as has been that which went before it, that this pursuit assures maximum production? The simple table given below, in which the data collected in the world-wide enquiry of 1934-38 are used again, proves that exchanges of foodstuffs during that period tended to be insufficient to meet the world's most urgent needs.

	Food Production	Food Consumption	Export Possibilties (+) or Import Requirements (−)	
	In vegetable calories per person per day (figures very approximate)			As a percentage of production
North America	10 000	8 577	+ 1 423	+ 14·23
Latin America	7 050	3 870	+ 3 180	+ 45
Western Europe	5 250	6 845	— 1 595	— 30·4
U.S.S.R.	4 600	4 650	— 50	— 1·09
East Asia	2 750	2 871	— 121	— 4·4
Certain islands in S. E. Asia	2 750	2 640	+ 110	+ 4

In western Europe, in particular, production prior to 1939 met hardly more than two-thirds of the demand. The deficit was covered by importing on

a very large scale from countries overseas with far lower productivity, which, with the exception of the United States, were able to export food only because of the low levels of nutrition of their own inhabitants. If the levels of nutrition in all these countries had been the same as that of the United States during the period with which we are dealing, 1934-38, the United States alone would have been in a position to export food.

Moreover, the disparity in production between the various regions is increasing, as is shown by the fact that the food production per head of population for the years 1952-53 and 1953-54 were: for the whole world, 101 and 102; for North America, 123 and 119; but for east Asia, 85 and 87.[2] It is clear, therefore, that the inhabitant of east Asia, with an income of the order of one-thirtieth of that of his North American counterpart, cannot buy from the latter any of his disposable surplus unless the normal "laws" of the market are somehow modified.

It is noteworthy, moreover, that, in all the countries where the primary needs of the people are not satisfied, the demands of groups with considerable purchasing power for the satisfaction of their secondary needs, and even for luxury goods, produce a profitable market which diverts the limited means available from the production of basic foods. As has been aptly remarked by M. P. Vinot, the pyramid of needs is "hollow". Economic progress demands a policy in relation to purchasing power which will remedy this situation.[4]

Such a policy cannot alone solve the problem, however, for the natural fluctuations of harvests, aggravated by the effects of King's law, may continue for a while, on account of the "time-lag",[5] to keep food production below the level required for the satisfaction of demand. Where, as in this case, it is a question of essential needs, the satisfaction of which governs actual production, one cannot rely on the machinery of the market.

As far back as the 16th century, we had Jean Bodin writing: "*I make an exception of wheat, the marketing of which should be controlled better than it is. For we go on having innumerable periods of high prices and famine, for the lack of such proper control . . . The way in which order might be produced in this connexion is to have in each town a Public Granary, as used to be done in properly-run towns, and to replace each year the old grain which has been drawn from it. By so doing, we can insure against seeing the prices go up as high as they have done, because, besides making provision for bad harvests, we would acquire the monopoly now held by the merchants who sow all the wheat, and who often buy it up before it is ripe, so as to be able to fix the prices as they want*". A century later, Vauban proposed to Louis XIV a system of stock-piling of which Lord Keynes would hardly have disapproved, and which bears some resemblance to the Enver Normal Granary of the Agricultural Adjustment Act of 1938.

As has been said by Professor A. Amar:[6] "*At the end of its evolution, the capitalist system is incapable of combining increased production with the*

maintenance of profit levels. If those levels are to be maintained, at any price, shortages must be defeated artificially. A system which is based on the idea of profits ends up by killing itself. The world of money has thus landed itself in a situation which is ridiculous, for capitalist economy can survive only by deliberately working below its capacity, and is thus in a blind-alley from which it can extricate itself only by denying its own principles".

In saying this, he is exposing again the contradiction between real "economies", "the art of acquisition", which "*confines itself to the procuring of the goods necessary for life and useful, either to the household or to the State*", and what it has become as the result of the intervention of the market, described by Aristotle as "crematory", for which "*the circulation of goods and money is the source of wealth*", and which "*seems to pivot around money, because money is the beginning and the end of this kind of exchange*". Karl Marx[7] took up the term used by Aristotle and has also done more justice to the physiocrats and their predecessors, Vauban, Boisguillebert and Petty. He certainly made a better study than did the "economists" of his time of the processes of production, but he neglected almost as completely as they did the matter of consumption, and it would be difficult to deny that he thought that, with the aid of technological progress, a better system of sharing out and distribution would be enough to produce a reign of justice and abundance.

* * *

Studies conducted in accordance with the scientific principles first laid down by Aristotle for the pursuit of human knowledge no longer leave room for the same optimism as before either as regards production[8] or as regards consumption[9]. The conclusions to which they have now led may serve, however, as a foundation of an economic science on which political action may be taken[10]. Prices and markets are no longer seen, except by a few old-fashioned adherents of the classical "Political Economy", as dominated by Laws which we cannot but accept, but as factors which can be adapted at will for the attainment of a policy of expansion and well-being.

It is thanks to such a policy that the United States found it possible to ensure the brutal expansion of their agricultural production during the second World War, and have been able to maintain it thereafter far beyond the limits which "the free play of the market" would have imposed. Guaranteed prices to the producers, and special prices, or even gifts, to certain consumers, both at home and abroad, are the means which have been used to keep the economic machine moving.

It is by deliberate action to restrict exports which deprive the population of essential products and which also destroy the productive capacity of the country that India has been able to improve the level of nutrition of her population. The best-known example of this policy is provided by ground-

nuts, clearly governed by the variations of South-North trade in this product through the Suez Canal. India has faith in this line of progress, which China abandoned in 1950 and 1951:

	South-North Trade in Groundnuts[3] (thousands of tons)				
	1937	1947	1948	1950	1951
Total	1 032	38	98	205	198
Including: India	876	25	76	38	37
China	64	8	6	74	123

So far as France is concerned, the evolution of her food economy after the end of the shortages due to the war has been towards a healthy policy of supply suitable for a Western Europe which can no longer live on the "pound of flesh" extorted from countries which it formerly dominated, and which are still under-developed and under-nourished:

France	Food Diet Level and Foreign Trade in Food Products[4] (Wines, ciders, beers and other beverages excluded) (Per head per day)					
	In ultimate calories		%	In vegetable calories		%
	Food Diet level	Net imports		Food Diet level	Net imports	
1934—38	2 755	757	28·6	6 399	779	17·2
1953—54	2 812	109	4·9	7 118	120	1·76

Let us leave it to the "crematory" theoreticians to mourn over "the traditional currents of international trade" and to protest against the "anti-economic" measures taken to obtain these results despite their efforts for a "freeing of exchanges" and a return to "parities of exchange". Let us simply remind them that, although G.A.T.T. (General Agreement on Tariffs and Trade) has not felt bound to apply Article VI of the Havana Charter, that Article is applicable to all basic products, and therefore to all agricultural products, and that nothing could be more "liberal" than it in spirit.

After the first World War, Part XIII of the Treaty of Versailles, which created the International Labour Organization (I.L.O.), declared that human labour is not a commodity which can be left exposed without protection to the so-called "laws of the market".

The greatest step forward which could be registered after the second World War would be the recognition that food is not just a commercial commodity like the others, and that it is the duty of all States to promote a food policy which is really "economic", or in other words, one which is calculated to "procure the goods necessary for life and useful, either to the household, or to the State"[7]. Such a policy must be judged, like the tree in the Bible, by its fruit, and not by its respect for the false gods of the "crematory".

Instead of leaving the "anti-economic" measures which are indispensible for a real economy to be denounced by the priests of Mammon, the God of Money, we must organize them on a world-wide scale, so that men will feed better, be more healthy, produce more, and eventually achieve the standard of well-being made possible by the technological level of our civilization.

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SOIL AND MAN

by

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Should the nature of the soil be taken into consideration in choosing a locality in which to live and bring up a family? Does it make any difference whether the beans and bananas, cabbage and cauliflower, oranges and onions, peas and potatoes, rye and rice, tea and tomatoes, wheat and wine we eat and drink were grown on soils that were formed from granite, limestone, sandstone, or shale?

Is a soil that has long been subjected to heavy rainfall capable of producing as nutritious feed and food crops as one that is located in a drier region? If not, would it be desirable for those who live in high-rainfall regions to import food from drier regions or irrigated arid lands? Should missing mineral elements required by animals and man but not by plants be supplied by way of the soil and crop rather than as supplements to the salt that is consumed?

Would it be desirable to substitute seasalt, with its great variety of mineral elements, for the nearly pure sodium chloride of common salt now in use? Or, would it be preferable to make supplemental use of a synthetic-salt mixture comparable to that of the ash of plants grown in mineral-rich soils? If the mineral elements needed by man were supplied in a balanced salt mixture, should this be made of organic or inorganic salts?

Is it important to animals and man whether farmers in acid-soil regions lime the land on which feed and food crops are being grown? Does it make any difference to the consumer whether the supplies of nitrogen and mineral nutrients in the soil are renewed by applications of chemical fertilizers rather than by the use of legumes and animal manures?

Do the chemically-very-different grey, brown, black, yellow and red soils of the Earth produce widely-different plant products that put their respective marks on the animals and men consuming them? If so, are these differences in effects due to differences in the mineral or the organic qualities of the plant produce, or to both?

If the mineral or organic quality of the plant produce of any given soil needs to be improved, can this best be done by fertilizing the soil, by breeding better plants of the same species, by growing other species of plants, or by making use of supplemental foods, natural or factory- synthesized, containing the missing constituents? Can a purely-plant diet be made equally as satisfactory for man as one that is supplemented by the edible products of animals?

These questions are not raised with the thought of dealing directly with them, since many doubts exist as to what the answers to many of them

should be. The thought is rather that, with these questions in mind, one can see more clearly the need for considering the fundamental principles involved in food production. Only then can dependable conclusions be drawn concerning the soil in relation to the mineral and organic nutrition of man.

Rocks, and the soils formed from them, constitute the nutritional starting-point for all the living things inhabiting the Earth. This applies whether these organisms live on the land, in the fresh water of the rivers and lakes that flow from it, or in the saltwater of the seas that surround it. Certain of the mineral elements in rocks and soils, certain of the gases in the atmosphere in and above the soil, and the water that is stored within the soil constitute the building blocks out of which all living things, whether plant or animal, are made.

But soil varies in its mineral makeup all the way from that of the unwashed desert sands to that of the highly insoluble residue that remains in the humid tropics after the rains of the centuries have carried all the soluble substances out to sea. Virtually all soils are highly productive when first put to the plough, assuming adequates supplies of water. But they vary markedly in their lasting properties for crop production. They differ greatly in colour and particle size. And differences in soils are still more apparent to the chemist who submits them to careful laboratory examination.

These differences in soils may be due not only to differences in the chemical composition of the rocks from which they were formed but to differences in the nature of the climate to which the rocks and soils have been subjected as well. And the kinds of plants associated with the soil-climate complex are highly important, since plants affect the nature of the soil on which they grow, and they become a part of the soil. Finally, the factor of time is involved. Some soils are young and changeable. Others are mature and stable. And still others are in advanced stages of decadent old age.

The younger a soil the more closely related it is to the rock material that went into its making. Some of our most productive soils have been derived from great glacial, loessial, and volcanic-ash deposits that have been laid down during relatively recent times. And the alluvial soils that cover the wide floodplains of the great rivers of the Earth consist of accumulations of rich topsoil that have been carried downstream from higher elevations over long periods of time. These young soils are normally very rich in all the mineral elements required by plants and animals, and usually in nitrogen as well.

Given time, however, climatic factors, together with those of the associated vegetation, become dominant. Wide expanses of soil under similar climatic and vegetative environmental conditions have become essentially uniform in appearance and chemical composition, no matter what the nature of the rocks from which they were formed. Thus, after long periods of time, soils

of such widely diverse origins as granite, limestone, and shale may come to have virtually identical properties.

The agricultural soils of the Earth can be conveniently classified into four great groups, based primarily on the long-term effects of the climate and associated vegetation on the underlying rock materials. These include the grey-red desertic soils, the brown-black chernozemic soils, the grey-brown podzolic soils, and the yellow-red latosolic soils, with transition groups of intermediate properties in between. A fifth large group would include all the alluvial soils, such as are found in the valleys of the Nile, Ganges, Amazon and Mississippi Rivers.

The grey-red desertic soils were formed under arid conditions and little or no vegetation. Their chemical composition closely resembles that of the underlying rocks, subject to such movement as has been effected by violent winds and the occasional heavy downpours of rain that have occurred. They have important agricultural value only as they can be brought under irrigation. When water is applied, they are usually found to contain large amounts of soluble salts, including the highly alkaline sodium and potassium carbonates and the less-alkaline and less-soluble calcium carbonate. Such soil are usually very productive, and plants grown on them are high in ash and protein. The primary problem is that of dealing with the excessive salinity and alkalinity that often develop when water is applied.

The brown-black chernozemic soils were formed under conditions of moderate rainfall and a natural grass cover. Their dark colour is due to organic-matter accumulations resulting from lush spring growth followed by drier summer conditions under which the rate of decomposition of the accumulated grass residues was relatively slow. The rainfall was sufficient to leach out the readily-soluble salts, including the alkaline sodium and potassium carbonates.

But the less-soluble calcium carbonate remained to stabilize the humus compounds and to form a calcareous deposit. The location of this deposit with reference to the surface of the soil depends on the amount of rainfall to which the soil has been subjected in relation to the amount of evaporation and transpiration. It may be on top of the soil, a foot or more below the surface, or down deep in the sub-soil. And, with increasing rainfall, it finally disappears entirely.

Chernozemic soils cover wide expanses of land, such as the great wheat-growing region of the Ukraine in the U.S.S.R. and the equally large corn and wheat belts of the United States, of North America and of Argentina in South America. These soils are highly productive of virtually any crop that is suited to their climatic environment. Such crops include the acid-sensitive alfalfas and sweet clovers that are noted for their high content of proteins and mineral elements.

During favourable years high acre yields of high-quality crops are possible on these soils. And these soils have lasting properties in that they continue to be productive for many years after being first planted to crops. The most

troublesome limiting factor is the frequent lack of adequate rainfall to meet crop requirements. This applies particularly to the drier portions of these soil areas where wheat becomes the dominant small grain and corn is largely replaced by the drought-resistant grain sorghums.

The grey-brown podzolic soils predominate over the cooler and moister agricultural regions of the Earth. These soils were formed under conditions of relatively high rainfall, low evaporation, temperate climate, and heavy forest vegetation. They have been subjected to more leaching than the chernozemic soils. Not only have the soluble salts and alkali carbonates been dissolved and carried away, but the calcium carbonate as well. As a result, these soils are relatively low in mineral nutrients and they tend to be strongly acid. Their usefulness for agricultural purposes depends on the extent to which liming materials and chemical fertilizers or animal manures are applied to them for nitrogen-and-mineral-replacement purposes.

The podzolic soils owe their special importance to the dependability of the moisture supplies and to the long summer days in the regions in which they exist. This makes them particularly valuable for the production of small grains, mixed hays and pasture grasses. And they are very useful for growing potatoes, vegetables and coolweather canning crops. Dairying and orcharding are important agricultural industries. But the high-protein and mineral-rich perennial legumes, like alfalfa, do not thrive naturally on them. To grow such crops special attention must be paid to liming the soil, and heavy applications of phosphate and potash must be made as well.

The yellow-red latosolic soils predominate over the humid sub-tropical and tropical regions of the Earth. The heavy rainfall in these regions, under the high temperatures that prevail, have carried away not only the soluble salts, including all the carbonates, but a large part of the silica, a primary constituent of most rock minerals, as well. Thus, these soils finally come to consist largely of iron, aluminium, and titanium oxides. They are not strongly acid and they do not require such heavy liming as the podzolic soils. Any lime that is applied has value primarily as a source of calcium for plant nutrient purposes, and it is important for bone construction in the men and animals that consume the plants.

Many people have had high hopes for the agriculture of the tropics. Crookes once grew oratorical on this subject when he addressed the British Association for the Advancement of Science some 60 years ago. He said:

"And in the next generation, instead of trusting mainly to foodstuffs which flourish in temperate climates, we probably shall trust more and more to the exuberant foodstuffs of the tropics, where, instead of one-yearly sober harvest jeopardized by any shrinkage of the scanty days of summer weather, or of the few inches of steady rainfall, Nature annually supplies heat and water enough to ripen two or three successive crops of foodstuffs in extraordinary abundance . . . We must develop and guide Nature's latent energies, we must utilize her inmost workshops, we must call into commercial

existence central Africa and Brazil to redress the balance of Odessa and Chicago".

But many problems are involved in maintaining adequate supplies of nitrogen and mineral nutrients in the rain-leached soils of these tropical regions. And loss of soil by erosion, once the protective forest cover has been removed, is a very troublesome matter to be dealt with. Stamp is more in accord with the facts when he labels the rain tropics as *"regions of lasting difficulty"*. And De la Rue says: *"The legend of the inexhaustible fertility of the soil of the hot countries has taken a long time to kill"*.

Certain tropical soils that have been derived from recent deposits of volcanic ash and have a base that can be made to hold water are highly productive for paddy rice. Other areas of these ash-derived soils are excellent for sugar-cane production and for tropical fruits. Some of the best developments along these lines have taken place in Java. And very great possibilities with rice are realizable in the Amazon Valley.

A number of important changes in the organic make-up of plants occurs as we pass from the irrigated desertic soils through the chernozemic and podzolic soils of the temperate regions to the latosolic soils of the tropics. The percentage of protein in plants grows less while that of the carbohydrates increases. Albrecht and his associates point out that the quality of the proteins is also lowered, with greater likelihood of deficiencies of some of the essential amino acids, notably tryptophane and methionine.

These changes in protein and amino-acid values are related in large part to changes in amounts and ratios of the several mineral elements at the plants' disposal and the amount of nitrogen available for use. Bear and associates have shown that the ash, calcium and trace-element contents of vegetables decrease from the desertic soils to the chernozemic soils and still further to the podzolic soils. The only exception is manganese, which is highest in the plant produce of the acid podzolic soils. Still further reduction in the percentages of ash elements in plants is to be expected as one passes to the latosolic soils of the tropics.

The sum of the calcium, magnesium, potassium and sodium in any given species and variety of plant, expressed as milliequivalents, tends to be a constant for any given climatic environment and specific stage of growth at harvest. But a wide range of values of each one of these elements can be found. As the content of potassium increases in plants, corresponding decreases occur in magnesium and calcium. Sodium plays very little part in this except in irrigated desert soils or where it has been applied in the form of fertilizer. If the plant absorbs its nitrogen in the ammonium form, this also alters the rate of absorption of the other alkaline elements.

This same principle of constancy applies to the intake of acid-forming elements absorbed by the plants. Increase in intake of nitrogen as the nitrate reduces the uptake of phosphorus and sulphur. The chloride ion enters the picture to a considerable extent in irrigated arid areas and as a result of the use of potassium chloride as a fertilizer in humid regions.

Any marked departure from the normal in mineral uptake of plants will affect the quality of the produce for human and animal consumption. Cattle grazing on Kansas wheat that was abnormally high in potassium developed grass tetany, due to deficiencies of calcium and magnesium. The calcium content of the food of the tropics is relatively low and, as a result, the people tend to be small in stature. Fortunately for the African negro, the sun, falling on his bare skin, permits of the synthesis of large amounts of vitamin D, a highly important aid to calcium absorption and utilization. De Castro points out that the negro's frame may be spare from the low calcium content of his diet, but his bony structure is solidly built.

Pygmies and Shetland ponies reflect deficiencies of calcium and probably of phosphorus in the food and feed. And De Castro applies the term "human ponies" to the Chinese and Japanese, their height and weight having been lowered by chronic malnutrition. When fed calcium- and protein-rich meat, eggs, and milk, these smaller races soon grow in size and weight. And the Shetland pony turns into a horse when taken to a region where the forage is high in minerals and protein.

A soil may be rich in all the mineral elements required by plants and yet be deficient in certain other elements that are essential to animals and man. Among these additional elements that often are in deficiency are sodium, cobalt, iodine, fluorine and chlorine. Use of common salt takes care of the need for sodium and chlorine. But the feed from large areas of land is deficient in cobalt with the result that animals suffer from anaemia, they are listless, they fail to gain weight, and they are sexually impotent. Similarly, there are large areas where the feed is deficient in iodine. The animals in these areas are subject to goitrous growths, and they give birth to hairless young.

Cobalt deficiency for livestock is remedied either by applying cobalt sulphate to the soil or by adding it to the feed. In many areas 2 g of cobalt sulphate are added to every ton of feed for dairy cows. Iodine is usually supplied as a constituent of the salt that is fed. Fluorine deficiency has not been reported in livestock.

Iodine deficiency in man is characterized by the large goitrous appendages that hang from the necks of those affected. In many areas almost every person once had such a growth. But this also has been brought under control by adding a trace of potassium iodide to the salt. In some areas fluorine is not supplied in adequate amounts by the food and traces of this element are being added to city water supplies for better control of dental caries.

Although the general procedure in supplying missing mineral elements needed by animals and man but having no known value to plants is by adding salts of these elements to feed, food or water, there are those who believe they would better be supplied by way of the soil. If this means merely that they will have been changed from an inorganic to an organic form in the plant, it should be possible to effect this equally well in a factory. But it is possible that absorption of the elements first by the plant may

result in the synthesis within the plant of additional organic compounds that have value to the consuming animal or to man. There is, as yet, no dependable proof of this.

The possibility exists that feed and food plants may have accumulated, without apparent injury to themselves, mineral elements that are highly toxic to animals and man. For example, a wide expanse of selenium-rich soil, derived largely from Cretaceous rocks, extends south-west from Canada across the semi-arid region of the United States to Mexico City, and probably on beyond. In this region certain species of *Astragalus, Xylorrhiza, Oonopsis* and *Stanleya* accumulate selenium to concentrations of as much as 15 000 parts/million of their dry weight.

The first symptoms of selenium toxicity in animals grazing on plants containing only moderate amounts of this element are malformation and sloughing off of the hoofs. Alexander reports that Marco Polo saw hoof-deformities of this type in his travels through Tartary. "Blind staggers", a more advanced stage of selenium poisoning, often leads to sudden death. Concentrations of 5 parts/million selenium in food and 0·5 p/m in milk or water are considered dangerous to man.

Molybdenum, an element that is essential to both plants and animals, may be highly toxic to animals when present in excessive amounts in the forage they consume. Plants normally contain between 1 and 3 p/m molybdenum on a dry-weight basis. Widespread areas of deficiency of this element for plants are known, notably in Australia and New Zealand. In certain other widely scattered areas, molybdenum concentrations in soils, and in the plants growing on them, are abnormally high. At 10 p/m molybdenum or higher in forage plants, troubles are often experienced with livestock, particularly if the forage is low in copper.

The symptoms of molybdenum poisoning in animals include severe diarrhoea, loss of hair, emaciation and, ultimately, death. The antidote is copper sulphate. As much as 10 p/m molybdenum has been found in plants growing on molybdenum-rich soils without noticeable injury to the plants themselves. One of the best ways of solving this problem is by growing forage crops on the land and hauling the molybdenum away in the harvested crop.

The primary urge of a plant is to reproduce itself. Even if plants were able to think, and if they acted accordingly, little consideration would probably be given to meeting the desires of animals or man. Plants have to be accepted as they are, subject to such changes in them as can be effected by breeding and selection, and by altering their environment. But corn cannot be changed to wheat, wheat to rice, apples to oranges, or grasses to clovers.

Operating largely on a touch-and-taste basis, animals find certain plants they prefer for forage, others they accept, and still others they reject. Some of these same plants are palatable to man. Others can be made so by cooking or by way of the edible products of the animals that consume them. Many

species of plants have had to be rejected by both animals and man because of their physical characteristics or because of the high content of some toxic or distasteful substance contained in them.

Feed standards for animals and food standards for man are formulated in terms of digestible nutrients, calories, amino acids, vitamins and mineral nutrients. The soil's only known contribution to these values is by way of the mineral nutrients it supplies, the nitrogen that is released from its organic matter, and the water it stores from that falling as rain. Some of the mineral nutrients serve as structural units in plants. This applies particularly to calcium, phosphorus and sulphur. But most of the mineral nutrients function primarily as catalytic agents in the synthesis of organic compounds. Some of these organic compounds are essential to the life processes within the plant. Others are not.

The organic compounds in plants that are commonly mentioned as being required by animals and man include the proteins, carbohydrates, oils and vitamins. But a great variety of subsidiary products are also present in plants. Some of these are responsible for distinctive odours and flavours, agreeable or otherwise. The organic composition of a plant depends not only on the inherent nature of the plant but on both the quantities and ratios of the soil-derived nutrient at the plant's disposal during the period of its growth. And the quantities and ratios of these mineral elements, as well as those of the organic constituents in plants, are important to man, no matter whether he obtains them by eating plants directly or by way of animals that consume the plants.

The diet of primitive man — a nomad — was arrived at by experimentation. It consisted of a variety of plants and their products. And this variety became an essential feature of his food. In due time the milk of animals was added to man's diet. But, according to Stevens, somewhere along the path of life man made a wrong turn. That wrong turn, he says, was the change from vegetarianism to the eating of meat. He credits our killing instincts to this. And wars and resulting starvation of millions of people constitute the end result.

But there are nutritional advantages in consuming the edible products of animals as well as those of plants. Meat and milk animals serve as concentrators of the foods that are most likely to be deficient in the diet of man. These include the amino acids, vitamins and mineral elements — notably calcium, phosphorus and the trace elements. Animals also serve as testing-agents against any nutritional abnormalities in the plants on which they feed, sometimes to the point of suffering seriously from deficiencies or excesses, even to the point of death.

Mineral deficiencies are much more likely to develop in animals than in man, assuming use of reasonable intelligence on the part of man as to choice of foods. The animal may have no choice but to eat the forage produced on the land where he is permitted to feed. But man normally has at his disposal a great variety of agricultural products from all over the

Earth. In proportion to his ability to buy what he chooses, he can become a product of all the important groups of soils. This makes it possible for him to have suitable balance in both his mineral and his organic diet. But it does not guarantee that this will be effected.

There is safety in the drinking of milk and the eating of the edible products of animals, including the vital organs. And, in a country of food surpluses, an animal economy is essential to the well-being of the nation. It provides a means of regulating crop surpluses, the consumption of animal products going up and down in relation to the supplies of grain available for animal feeds. Where food is scarce, in most of the densely populated countries, there is no economy in feeding grains to livestock and then consuming their meat and milk. Russell points out that at least 80 per cent of the caloric value of a grain is lost by feeding it to dairy cows and over 90 per cent by feeding it to beef animals. And the efficiency of the transformation of plant proteins to animal proteins is only a little greater than this.

In proportion as we find it necessary to eat grains and other edible plant products as such rather than in the form of animal products, extra precautions must be taken to see that amino-acid, vitamin and mineral values measure up to the requirements. Plants grown on irrigated arid and subhumid lands of the temperate zones are much more likely to meet all the nutrient needs of man than those grown in the high-rainfall regions, and particularly in the tropics.

The agricultural-lime and the fertilizer industries have come to our aid in this connexion. They provide the means by which the nitrogen and mineral supplies in the soil can be replenished. And if fertilizers are so formulated as to supply by way of the soil all the needs of the better types of crop plants, the amino-acid, vitamin and mineral requirements of man can be met almost as well in the tropics as in the temperate zones and in the irrigated arid regions.

Yet, by and large, these possibilities are not realizable in the hot, high-rainfall regions because of the general lethargy of the people of those regions. This lethargy is due largely to malnutrition, in terms of both quantity and quality of food, notwithstanding that these people are living in the midst of many possibilities for abundant food production.

De Castro says that "*the so-called inferior races turn out to be starved races; properly nourished they are in all respects equal to the would-be superior races. . . . Not only by acting on his body — degrading him in size, withering his flesh, gnawing at his viscera, and opening wounds in his skin — does hunger destroy the human being. It also acts on his spirit, on his mental structure, and on his social conduct.*"

The problem of over-population and the reasons for it come prominently to mind in this connexion. It is generally assumed that over-population is the cause of hunger. But De Castro contents that the reverse is true. He says:

"It is known that there is a direct connexion between the functioning of the liver and ovaries, the role of the liver being to inactivate the oestrogens which the ovaries throw into the blood stream. Fatty degeneration of the liver and the tendency toward cirrhosis . . . are among the characteristics of protein tendency. These are very common in the Far East and in certain tropical areas of other continents. When degeneration of the liver occurs, it begin to operate less efficiently, and is less effective in its job of inactivating excess oestrogens. The result is a marked increase in woman's reproductive capacity".

Albrecht does not agree with this concept, at least in its application to animals. He thinks we need to consider the food problem as primarily one of producing proteins in quantity and quality for growth, protection and reproduction. All the necessary amino acids must be supplied in suitable amounts and balance. *"A high intake of proteins seems to me, in the light of the whole chain of living evidence, to increase both fecundity and longevity".*

Top-quality food, whether it be for animals or man, comes from top-quality soils. Top-quality soils supply plants with an abundance of all the mineral elements required, and in suitable balance. These may be present naturally in the soil — as in the better irrigated arid regions — or they may have to be supplied in fertilizer form. And nitrogen must be available in abundant supply as well whether by microbial fixation or that of the air-nitrogen factory. Possibly the extra elements known to be needed only by animals and man, if not naturally present in the soil, should be supplied by way of the soil as fertilizer constituents. But the evidence on this point is far from conclusive.

It is conceivable that we shall be successful in due time in putting the blue-gree algae to work on a factory scale to produce protein concentrates containing all the essential amino acid needed for supplementing the natural foods in densely populated areas. Or we may succeed in uncovering the secret of the chlorophyll molecule of green plants to the end that sugar can be produced in any quantity that may be desired. Large-scale microbial synthesis of proteins from sugar and fertilizer salts could then be effected. And it seems quite probable that improved salt mixtures can be developed as supplements to or substitutes for common salt. By these means we should be able to make up for the nutritional deficiencies of the foods of the less-favoured regions of the Earth.

It should be added that availability of good foods, even when supplied at reasonable prices, does not guarantee their proper use. Small children and old people in particular are quite likely to consume too large a percentage of high-carbohydrate and low-mineral foods. Much has already been done to make breads, pastries, candies, ice creams and soft drinks better-balanced foods. But much more could be done. Although all of these are products of the soil they bear very little resemblance to the original produce of the soil.

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AGRICULTURAL TECHNIQUE IN THE FIGHT AGAINST HUNGER

by

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I have been trying to find a good definition of the "art" of agriculture, which depends on a variety of sciences, and beg my readers' indulgence if I coin one by proposing "*the production of artificial conditions*". Agriculture tries to make the natural conditions in which a plant is grown — more particularly the soil and the climate — more conducive to its growth, while, at the same time, protecting it from the numerous enemies which are always ready to prey upon it. It tries to feed the animal to look after it, and sometimes to protect it, at least against more violent climatic changes. That is the difference between agriculture and cropping, the earlier way of obtaining food, which consisted simply of collecting what Nature produces — natural vegetation, wild game, fish — and it is therefore perhaps permissible for me, as an agronomist, to think that it is by agriculture, above all, that Man has made himself different from other animals which live on natural products.

I propose to deal here, first of all, with some of the more important ways in which artificial conditions are produced, showing what they involve and what possibilities they open up, starting with those which are most general, such as *tilling the soil* and *the use of fertilizers*. I shall then deal with *the provision of clean water* and draining, irrigation, and go on from that to that extreme of artificial conditions, *horticulture*. After that, I will go into the special conditions in tropical countries, and will conclude with an examination of the immense possibilities of modern agricultural methods, and of the vast capital investment and very wide knowledge without which the fine promises I shall have described cannot be realized, and hunger cannot be banished.

The first step in producing artificial conditions: tilling the soil

The best symbol for Agriculture is the hoe and its derivative, the plough,[1] which makes it possible to lighten the soil and to render it penetrable by roots, and also by water and air, thus favouring the development of the system of roots, as well as allowing oxidation and transformation of organic matter.

The agriculturist of the Middle Ages used to till his fallow land three or four times before sowing his wheat, a costly, inefficient kind of preparation which is still continued anachronistically by far too many peasants, either because they are attached to tradition, or, more often, because they have not the means to acquire modern equipment. Modern agriculture in-

volves less tilling, but it lightens the soil more and is cheaper, using a whole range of machines, including harrows, disk-ploughs, subsoil ploughs, rollers, and even rotary machines.

The more advanced preparation of the soil produces a finer "sowing bed", in which the earth has been lightened more and then pressed together. Combined with superficial sowing, it produces the most important conditions for a good start, and thus for a high crop yield. It calls, however, for plenty of power, the availability of which may be seen everywhere as limiting the possibilities of agricultural production. There was no possibility of increasing this quickly while Man had the use of only his own arms, which meant less than one-tenth of a horse-power. Animal power multiplied his resources and the fact that this has been developed more in western Europe than elsewhere accounts for the relatively more rapid development of that part of the world in recent centuries. For its full development it has been necessary to feed the draught animals better, which has been achieved (as in the case of human feeding) by transition from simple harvest products, for their feeding, to various kinds of special fodder crops.

Once this evolution got under way, it became possible to increase the supply of foodstuffs of animal origin, meat and milk. It is far from being completed, however, for in France alone there are more than twelve million hectares of *permanent pasture land* where, as the name indicates, the land is never tilled. The absence of this essential factor of production allows that land to stagnate in the stage of pastoral economy, and reduces its productivity to a very modest level: the equivalent in grass or hay of 13 quintals of barley per hectare. In the more continental, and drier, parts of our country, this average falls even to 10 quintals.

By advising the farmers of Lyonnais, which is in this drier region, to adopt the English "ley-farming" (adapted to their more arid conditions), P. Chazal and I have raised their production to levels of between 40 and 70 quintals. These figures have been achieved with meadows temporarily used for pasturage, based on seed-grasses, or with artificial meadows, for mowing, based on leguminous plants, and by tilling the soil only once every three or four years. By tilling more frequently, and growing two crops in a year (vetches and winter barley followed by forage maize), we have surpassed the equivalent of 100—120 quintals.

In order to achieve these figures, we also introduced artificial fertilizers, which will be dealt with in the next section, but this would be far less effective without the tilling of the soil: whence the frequent economic disappointment following the manuring of old meadowland.

On an estimate that, out of 12·5 million hectares of pastureland in France, 8 millions are easily ploughable and are worth being transformed as has been described, one may easily appreciate the extent to which production could be increased in the one area mentioned alone. French agriculture has,

in fact, greater potentialities of increase than that of any other part of western Europe.

The rapid increase of the world's population has converted us from the use of natural grasses to cultivated grasses. Will it carry us tomorrow from the natural forest to the cultivatel tree? In the poplar groves of Lombardy, the tilling of the soil, combined with the use of fertilizers and irrigation, make it possible to "harvest" a one-cubic metre tree eleven years after it has been planted, instead of 25 years: and during the first three years the soil produces usual agricultural products, such as lucerne or maize, wheat or beetroots.

In order to extend the field over which tilling of the soil can be applied, increased supply of power is essential, and as a matter of fact, since the 1920's, the tractor, which provides this, has produced a real revolution in the conditions of agricultural production in those parts of the country where it is available. This revolution is somewhat comparable — despite certain difference of structure — with that produced in industry by the introduction of the steam engine, in the last century.

The internal-combustion engine, more flexible and handier than the steam engine, provides a new source of power, deriving its energy from fuel extracted from under the earth. But, in order to make use of it, we must have metal and must turn it into complicated machinery. The farmer of today must therefore dispose of far more than that accumulation of past work known as Capital, than did his ancestors.

The second step: fertilizing the soil

Primitive agriculture contented itself with a sort of natural fertilizing, still practised over a very wide area, especially in the tropics, produced by intermittent cultivation, short periods under crops alternating with long periods of lying fallow. In the equatorial zone, during the fallow period the trees draw fertilizing elements from the under-soil, and deposit these on the surface, in the form of an abundant humus of fallen laves and other detritus. This is burned, when the ground is cleared for cultivation, and its ashes, rich in the fertilizing elements just mentioned, provide an immediate supply of fertilizer for the new crops.

This technique involves a frightful wastage of fertilizers, however, and especially of nitrogen, most of which goes off in smoke, while the torrential rains wash away most of the good that is in the ashes. It is even less effective in the laying fallow under grass, which is practised in the savannahs of the tropics, as the grass roots do not penetrate so far down, while the wind which follows the "bush fires" very soon scatters the ashes away.

Any larger domestic animal which may be around is usually left to wander at will during most of the year, though it is sometimes shut in on a field after the crop has been harvested (as, for instance, after the harvest-

ing of the sorghum in the Sudan), to feed on the dried leaves of whatever has been grown there; and then it drops some manure about. The area immediately surrounding a habitation always has the benefit of the household ashes, and of the excreta of human beings and of the more domestic animals.[2] Though this way of fertilizing the soil is not always very deliberate, the mere fact that the fertilizers mentioned are scattered around the habitation improves the soil. It is this which has made it possible to move on quickly from this form of cultivation, forerunner of horticulture, to the permanent cultivation of the soil.

The plains and deltas of the Far East became very early the seats of dense populations which have been able to practise this permanent cultivation of the soil for at least three thousand years, thanks to the systematic, and in their case well thought out, use of all their available resources of fertilizers.

Human manure is the best known fertilizer, of course, but there are numerous others, such as vegetable waste or "green fertilizers", household ashes, kitchen debris, the husks of rice grain, mud from ponds and the alluvial deposit of rivers, besides industrial waste-products, like oil cake and slaughter-house debris.[3]

In north-western Europe the excreta of animals early assumed a specially important role, solid and liquid manure being collected more or less carefully for use on the farm. The high density of the livestock population there (which was impossible in the Far East because it was too overpopulated) increased later by the cultivation of forage crops, facilitated the transition by this means to continuous cultivation, which became more and more widely extended away from the farmhouse or farming centre as the means of transportation improved.

Further away from the villages, however, intermittent cultivation persisted for a long time, on the "*essarts*" of the Ardennes the "*savarts*" of Champagne, and the "*landes*" of Britanny and of the Basque country, and I have found them in existence even today at Revest-du-Bion, in the Basses-Alpes of France.

The great revolution in fertilizing dates from the second half of the 19th century, when chemical fertilizers came into general use: nitrates (Chile nitrate, ammonium sulphate): phosphates (natural phosphates, soon changed into superphosphates by treatment with sulphuric acid): phosphoric slag (a by-product of the steel industry). The end of the same century saw the appearance of potash fertilizers which are of less importance except for the more acid soils of the northern countries.

This artificial fertilizing represents, in what may be called the field of chemical energy, a revolution at least as important as the tractor. From the 15 to 20 quintals of wheat per hectare which the good Flemish farmers were getting at the beginning of the 19th century, we have gone on through 40 and 50 quintals to as much as 72 quintals per hectare.

By the combination of these two factors, cultivating the soil improved with fertilizers, it has been possible to remove from the garden into the open field the cultivation of plants requiring more care, still called "vegetables" by the farmers of the west, but known by agronomists as "weeded plants". Sugar-beet and potatoes provide more calories per hectare, and feed more people than do cereals. European agriculture is no longer "one great wheat factory", as used to be said in the 18th Century, and is moving away more from the cultivation of cereals only but, although the area under wheat has diminished to below that under "weeded plants", the wheat production goes on increasing.

The third step: water control

The plant of today, as "produced" by the geneticist, is not only more productive, it is also more demanding, and less simple — like a well-bred animal. After the soil for it has been broken up and fertilized, it must have a regular supply of water, varying little either above or below the optimum level.

Maritime climates are better than others, but when the subsoil is impermeable, preventing surplus rainfall from draining down though it, the soil soon becomes marshy and short of oxygen, and therefore unsuitable for the good development of cultivated plants. Drainage, by means of earthenware pipes sunk in trenches dug for the purpose, has produced such an improvement at Brie, that it is now better than Beauce, once a byword for fertility. The cleaning up of marshy valleys makes it possible to create (or recreate) good pasture-land out of ground formerly suitable only for growing reeds, rushes and other plants as litter. The brave Dutch have shown us how land can be reclaimed from the salt-marshes along the coasts, and eventually even from the sea.

In dry countries, on the other hand, it is lack of water which is the primary factor limiting agricultural production. Irrigation has been known since the very earliest times, and was practised in the first centres of agricultural civilization, such as Mesopotamia, India and South China. It is in process of large scale development now in the semi-arid zones from Egypt and the Mediterranean to what used to be called Turkestan, in Western Asia, and in North America (California). It is a much more delicate operation than drainage of wet soils, however, because it is successful only when an adequate supply is accompanied by really good drainage: otherwise salt may come to the surface (as at Relizane, Algeria). It calls for good farming, or the soil may become ruined by alkalinity, or by erosion, through misuse of the water. And finally, it calls for good tillage, for "*an old field is not worth the watering*" (Plain of Fores). But if done properly, it leads to very high production.

Even in a temperate climate, with plenty of water, irrigation makes it possible to have two crops a year, each with a very high yield. I have

myself seen, near Vercelli, between Milan and Turin, between Piemont and Lombardy, a wheat crop with a yield of 55 quintals a hectare harvested on 11 June and followed by rice transplanted on 13 June, which was harvested on 15 October, with a yield of 93 quintals a hectare, which means that the soil there yielded no less than 148 quintals of grain a hectare in one year!

Irrigation is being developed increasingly in its latest form, that of sprinkling, in imitation of the rain, which is used to complement the rainfall even in such northern countries as Switzerland and Germany, or as the U.S.A. and Norway. This form of irrigation can be used on ground which has not been levelled. It permits of an optimum dosage with water, and the best utilization of water, the latter being most important, of course, where the supply is limited. What is perhaps most important of all, however, is that it avoids the depletion of the soil by being washed through. It is far superior to irrigation by gravity, which makes water flow over the surface of the soil, but it necessitates metal, for pumps and piping, motors, and the power to drive them — in other words, capital, of accumulated work. The same might have been stated earlier, of course, in relation to drainage.

The economic limit to artificial conditions

The control of water is a still more advanced way of correcting natural conditions, but in the northen countries there is yet another obstacle to the rapid sprouting of vegetation: frost and cold. This relates particularly to species which, because of their tropical origin, are sensitive to cold. For centuries past the market-gardeners round the towns have countered this obstacle by sheltering their early vegetables under cloches and frames, or in greenhouses which are artifically heated by the fermentation of horse manure, by the circulation of warm water, or, more recently, electrically.

I have come across, in the Dutch village of Aalsmeer,[1] on the edge of the Haarlem polder, an example of unusually advanced artifical conditions, for flowers grown in frames, where the cultural medium is prepared to suit the species of plant, gravel, sand or peat being used, mixed in varying degrees with manure or fertilizers, to produce a soil which does not occur in nature. The plants are in pots or tubs, at waist-level, to facilitate handling. The climate in their greenhouses is absolutely artificial, the temperature, watering and humidity of the atmosphere being under human control.

Though it may be said that there is no technical limit to the development of artificial conditions, there is a very strict one of an economic character. The exploitation of 1·5 hectares of land involves an investment of 150 million francs, which means 100 million francs a hectare, or £ 40 000 an acre! It employs 27 men a hectare. This means that the plants grown must be only the most costly. And already the early vegetables imported from the more sunny countries are competing successfully with those grown in the northern lands.

Soil-less cultivation also has very great possibilities, but one must not lose sight of its economic limitations and must carefully consider its cost, measured in terms of "real wealth", though this will tend to fall with the advance of technique.

Special problems of tropical regions

We have seen that the temperate regions can achieve very great and very rapid increase of their agricultural production only by recourse to various known measures (of which some examples only have been mentioned here; there has been no reference, for example, to the essential role of genetics or of humus). In dealing with regions in the tropics, however, certain reserves must be made. In western and central equatorial Africa, which are always humid, systematic attempts at continuous cultivation, which were made with the object of liberating them from bitter subjection to lying fallow under forest (1 to 2 years of cultivation alternating with 11 to 18 years lying fallow), were complete failures.[5]. The station of Yangambi, in the Belgian Congo, has so far succeeded in prolonging the productive period up to four years only, and in so doing had been unable to dispense with the necessity of a fallow period for restoring fertility or, therefore, with the hard work involved in clearing the land at the beginning of each period under cultivation.

The possibilities of "getting by", by adopting continuous cultivation, seem to be more immediate in the tropical zone, where the single rainy season depletes the soil less, and where the presence of numerous livestock makes it reasonable to expect supplies of manure. But even there such possibility disappears if the manure has to be carried on the heads of women, in baskets of 25 to 30 kilograms, so that a thousand or so trips of 10 to 12 kilometres there and back must be made to give virgin fields the dosage of 30 tons of manure a hectare, which is considered "normal" in Europe. The first necessities are roads, and a wagon with draught animals, or better a tractor, and the next thing to do is to have the field closer to the farmhouse. Far removed from communications, one must pay high for one's fertilizer and sell one's produce cheaply, for each of these has to bear the burden of an exaggerated series of transport services, and an even heavier burden in relation to the costs of distribution.

The golden rule, that the essential bases of modern agriculture are eqipment in general and mechanization, applies also in the tropics. Even in tropical conditions, with two rainy seasons, it is possible to practise continuous cultivation without ruining the soil, by having plantations of trees or shrubs (oil-palm, cocoa, coffee). The key role in the struggle against hunger is probably that played by the irrigated rice-field at the bottom of a valley, for there the soil can be exploited continuously without risk of impoverishment. For slopes and plateaux, however, the transition to continuous cultivation of annual plants is still a difficult problem to solve. It is

to the solution of this problem, therefore, that agricultural research throughout the world should devote its main effort and the requisite resources.

Immense possibilities and vast demands of modern agriculture

Modern techniques, if applied on an adequate scale, would make it possible to raise agricultural production rapidly, and thus to win spectacular victories in the war against hunger. Care must be exercised, however, especially until systems of agriculture in the tropics which are not destructive have been perfected. For, on the one hand, our agriculture is still too wasteful in respect of man's heritage of land, particularly by erosion, while on the other hand, in order to feed the existing population of the world more or less adequately, agricultural production must be doubled forthwith. Moreover, because mankind believes in ever increasing speed, we are approaching a biological disequilibrium which is not without danger.

Demographic evolution is worrying the agronomist who feels himself responsible in relation to hunger in the world, and moves him to make urgent demands for the powerful means without which he cannot combat that hunger. So far, however, he has not been accorded these means, which correspond roughly in scale to those which are devoted to armaments by all the countries. The transfer of these means from the latter field to the former is clearly desirable, and would become easier in an atmosphere of peace. More favoured, in this respect, medicine has been able to increase the number of mouths to feed.

The noble aim which is at stake in this difficult struggle obliges us, therefore, to reconsider problems in relation to the economic structure which determine the direction of investment and of capital resources. An economy which aims at profits is intrinsically unable to accord first priority in the allocation of resources to increase the production of basic foodstuffs, as is required. It must satisfy first the demands of the privileged, and make luxury motor-cars before bull-dozers to fight erosion, and tractors to till the field, while the soldiers use the raw materials of nitrogen fertilizers for the manufacture of explosives. Agriculture, which rural economists often call "an industry with small profits", has never received the governmental solicitude which it deserves, but there are signs now of a change for the better in this connexion, and we should encourage it.

There is no question, of course, of dreaming of a utopian society, purely agrarian and non-industrialized, as did the Croatian Peasant Party around 1930. The battle against hunger in the 20th Century cannot be won with a neolithic hoe, but demands, as has been shown earlier in this article, the whole arsenal of modern technology, which means plenty of capital and plenty of power. It demands also, in the first place, tens — or better hundreds — of thousands of highly trained agricultural experts, to do research work, to popularize techniques which have been found effective, and to teach the future farmers; together with factories for the production of fertilizers and

insecticides, of tractors and modern equipment; but above all, power, and here nuclear energy offers timely aid to petrol and electicity.

Agricultural production is nowadays achieved more in the factory than in the field, and this justifies the well-known "exodus from the land". As Professor de Castro has shown so clearly, it is the purely rural societies which suffer the most from hunger. Present day methods of agricultural production demand the rapid and simultaneous supply to the underdeveloped countries of all the techniques and the capital equipment, since these become fully productive only if combined. This cannot be done on the scale required as a profitable venture, so the equipping of Asia, Africa, South America and of southern and eastern Europe, will demand considerable expenditure which cannot be recovered.

The idea of human solidarity (definitely not economic) will have to develop more and more, both inside the nations and among them. The economy of abundance, or the right against hunger, which we must promote will deploy the means at our disposal in accordance with priorities based on social value, and in the first place in accordance with their effectiveness in producing a rapid increase in the food available.

Economy based on profits is becoming weaker and, having difficulty in adapting itself to a situation of relative abundance (relative, that is to say, to an inadequate purchasing power), is tending towards a futile malthusianism, towards a reduction to destitutism. This will shortly lead to its general condemnation, if we persist in exposing its defects.

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[1] Read their history in the magnificent work "Man and the Plough throughout the World" by A. G. Haudricourt and Jean Brunhes-Delmamarra. N.R.F. Paris.

[2] The Greek agricultural statistics still draw a distinction between "domestic" animals (goats and sheep, which stay close to the house) and "nomads".

[3] See the more detailed list, drawn up in North Viet-Nam, in my book "Rice-growing in the Tonking Delta". *Société d'Edition Géographiques maritimes et coloniales*. Paris, 1935.

[4] See Chapter XII of my book "Agricultural Economy in the World", published by *Dalloz*, which has recently been published in English by *Methuen*, London.

[5] "Agricultural Economy in the World", Chapter I.

THE STRUCTURE OF AGRICULTURE AND THE FOOD PROBLEM

by

J. M. Gatheron, France

In the beginning, man, then nomad or only half-settled, procured his nourishment from wild fruit and vegetables which he picked, supplemented by the fruits of fishing and the chase. Later, he discovered that he could be more sure of having something to eat if he cultivated the land. This development made him feel a proprietary link between himself and the land, because of the work that he put into the soil, and because the joint fruit of his work and of the soil was a necessity for his livelihood.

This conception is still common among primitive peoples, who regard property as a relationship between themselves and the universe, both natural and supernatural, which has mysterious power to exercise sovereign rights that cannot be usurped over people and things. They regard the land as belonging to the gods, and think that man has the right to make use of it only for the purpose of providing for his needs by his own work. There can be no question, therefore, of inheriting it, and the only things that man can regard as belonging to him are those which he needs for the continuance of his existence, such as his tools, his arms, his clothing and the fruits of his own labour — of all else he is merely the tenant.

This conception is extended to cover all the collective groups to which the individual belongs naturally from the time of his birth: the family, the clan, the tribe, the village. The idea of ownership is thus accorded a social character, and the sovereignty of supernatural or supranatural powers is exercised indirectly, through delegates who are, by tradition, ritually appointed by the social group (tribe, clan, village etc.). These delegates decide the policy of the unit, notably as regards its relationship with the land from which it derives its food. Various groups stake their claims for territory over which they propose to exercise their user's rights — not without conflict with their neighbours, since there is truth in the saying: "He who has land, has also war" — and then distribute it among their smallest units, the families, for cultivation. In some ethnical groups in Africa this distribution is done, in each village, by a "Lord of the Land", who is responsible also for the vital problem of drought, and who, by virtue of the magical power with which he is credited, of being able to control the rain, becomes the Lord of the Crops.

Man's ownership of land is not rigidly fixed

The division of territory between ethnic groups (tribes, clans) or social groups (villages), as also the distribution of this territory within those groups, is subject to constant revision.

A group situated in the middle of a wide area within which commercial exchanges are very limiteed, and finding itself threatened with famine, as the result of bad harvests, may seek a direct way out of its predicament by pillaging its neighbours. Where, however, the famine is due to an increase of population, it becomes necessary to conquer new territories, and if these are already occupied, the process generally involves bloodshed. Such cases have always been frequent in countries where agriculture is primitive, but they do not, of coure, constitute the only cause of conflicts and of revisions of territorial, political and social boundaries.

Within groups, like the village, which come immediately above the family, the distribution of the land has always, since the very beginning of agriculture right up to the time rigidly legalistic political regimes came into being, been governed by a certain customary flexibility. Such distribution has had to be revised, from time to time, more or less in accordance with variations in the size of various families, or with increases in the number of families.

It will be seen from the foregoing analysis that man's ownership of land is always conditioned by three fundamental factors: the possibilities of agricultural production, harvest variations, and demographic movements. Man has always tended naturally to divide up the land in accordance with food requirements.

It would be a mistake, however, to think that the actual division of the land among groups is in accordance with some unique and invariable system. It is not the product of a system: its methods have varied infinitely, both in time and in space, not only in accordance with the needs of political, ethnical or social groups, but also according to technical conditions and to the concepts, usually myths, that inspire the organization of human relations within groups. This explains how it is that, in a belt across northern Europe, from England to Russia, we find traces of land distribution like a jigsaw puzzle which pre-date by a long time the "open field" principle which succeeded it. This distribution of the land in closed fields of irregular shape probably dates back to a civilization with a social order different from that which produced cultivation in parallel strips. The distribution of the land was probably then based on the possession by the family of a horse, which could be used for ploughing, but also for war. Increase of the numbers of livestock and, relatively speaking, of the human population, tended to stabilize the ethnic groups, and this, in turn, led to the organization of production and to more complete utilization of fodder resources by the introduction of free pasturage, which brought the "open fields" into being. The traces left behind by these transformations are open to various interpretation, of course, but it would seem certain, at any rate, that the land belonged to various ethnic or social groups, and that, for its use, it was distributed among families.

The communal regime and its displacement by private ownership

Where agriculture is primitive and stagnant, and there is little possibility of commercial exchanges, so long as there is no further cultivable land available, the territory cultivated by a stationary group is usually re-distributed among the matrimonial or patriarchal families in accordance with their needs and with their ability to work it (numbers of adult men and of draught animals). The essential bases of such a system are the aggregate need of the human individual and of his working capacity, within the framework of the family. It is limited by local conditions and by the technique employed. It takes into account the necessity of mutual aid in defence against natural adversities and against external ethnical or political threats. It is for this reason that human groups have coalesced into small units of which the most prevalent, in Europe, are the Mediterranean city, or the village, which is the commonest morphological expression of the commune.

By this process there came into being the communal regime, of which the basic characteristic is the pooling of property, and more particularly the common ownership of the land. This regime corresponds historically with an agricultural economy to meet actual requirements, and excludes any kind of speculation. If however, it did not suffer from the excesses to which speculation leads, it also did not evolve towards the development of production and the technical improvements which make it possible to raise standards of living.

The disappearance of the communal regime as the result of the dissolution of primitive agrarian structures was accompanied, on the contrary, by the development of industrial economy, which it fostered by providing industry with the manpower of landless men, ready to accept the most degrading working conditions.

A very clear example of this is provided by England, where the practice of enclosure, which put an end to the common land owned by the villages, developed so much between the 12th and 18th centuries that by 1750 the land was worked by 7 per cent of the population and owned by only 2 per cent, after which, of course, agricultural production fell far below the country's requirements.

The former communal peasantry, gradually forced off the land, was reduced to the condition of the urban proletariat, to the advantage of industrial capitalism, and for many centuries afterwards its living conditions were lower than those of its free ancestors on the common lands. These conditions could not be improved until the increased development of industry and of trade, due to the introduction of steam, brought cheap agricultural products from the colonies to the English ports.

The extension of speculative agriculture to countries outside Europe resulted, in fact, from the search of the European countries, headed by

England, for cheap agricultural products for their working people. It enabled the costs of industrial production to be kept as low as possible, and industry to be supplied with materials on favourable terms.

In Europe itself, development on the basis of an industrial capitalist economy sometimes profoundly altered the structure and character of the agricultural system. Thus, in France, where the land was freed from its feudal usurpers by the Revolution of 1789, and passed into the hands of the bourgeoisie of the towns and countryside, it subsequently became split up, either by the action of the Civil Code governing inheritance, or by the purchase of small-holdings by the peasants, as occasion presented itself. The increase of the population of Europe from 175, to 500 million inhabitants in the course of the 19th century demanded increasing agricultural production, of which an ever-growing proportion was destined for sale. With agricultural technique still not far in advance of that of former generations, the yield of the soil remained dependent on the work put into it and on its being fertilized with natural manure, with the result that a large farming population became necessary. Thus the conditions of production and the prevailing customs combined to foster the multiplication of farms. It had, in fact, to be recognized that the land was farmed better when the farmer owned it, but an even more important factor in this connexion was that landed property gave prestige.

In France, the number of tax accounts, representing thee number of taxable properties in each commune, rose from 10 296 693 in 1826, to 14 335 738 in 1882, despite the loss of Alsace and Lorraine. It is true that production also increased over that period, but this was due largely to the extension of the area under cultivation and to better alternation of crops, and in spite of it, France has been obliged to import wheat regularly since the middle of the 19th century, just as England has been since the end of the 18th century.

Various types of holding and progressive agriculture

When all is said and done, however, it is undoubtedly a fact, which has been proved in every country right up to the present day, that the division of the land among small and medium individual proprietors leads to an increase of agricultural production. But there are exceptions to this rule, as, for instance, in England, in the 19th century, when the demand for land was so keen that the farmers were forced to grant leases at very high rentals, and adopted the practice of "culture for leave", which exhausts the soil and eliminates labour.

Partition of the land, when carried to the extreme, often landed the owner-farmer in an intolerable economic situation, for the splitting up of the land into small-holdings entailed a variegation of its cultivation which proved incompatible, in the long run, with any rational organization of production.

Nevertheless, where the small-holding is a relatively stable nucleus of an estate, it has been found to be good for delicate cultures which provide high-quality products, and which demand careful handling by skilled workers with special technical knowledge, combined with the maintenance of the soil in a high state of fertility. Examples of such cultures are vines for the production of high-quality wines, tobacco, flowers, fruit-trees, high-quality cheeses like le Comté, and so on. In this respect, recent developments in agricultural technique have not appreciably modified historical experience. Considered as a whole, however, these cultures are limited to luxury products and do not meet basic alimentary needs.

The prosperity of individual small-holder production has had only a short history — a little more than 100 years in Europe — and ownership has not always been necessary for the perfection of agricultural techniques, or for the increase and improvement of production. The organization of the relationship between the owner and the exploiter exercises as decisive an influence as does the ownership of the land by the exploiter. It may seem surprising, but crop-sharing has sometimes yielded very good results, both technical and economic. This is the case, for instance, with fruit-growing (peaches in the valley of l'Eyrieux, in France) and with the best stock-raising (Charolais Limousin).

In the west of France one finds, besides the more usual types of leasehold, special types designed to meet the fundamental requirements of the exploiter, who is anxious not to lose the fruits of his labour. Thus, for example, there is what is called a lease "*à comptant*", which guarantees to the sitting vine-grower that he shall have tenure of the land during the lifetime of the vines that he has planted. Another example is the "*bail à domaine congéable*", which guarantees to the tenant that any expenditure by him on building or on amelioration of the land during his tenancy will be refunded to him when his lease is terminated. In the latter case, the value of the work is often so considerable that the landlord woud think twice before evicting his tenant. These types of lease are relics of the system of land-tenure prevalent in the Middle Ages, whereby the "tenant" held the land in perpetuity, and had the right to pass it on to his descendants or to his partners, but not to let it out.

In the Middle Ages, however, under the feudal regime, land which was not thus passed on, returned to the landlord, and, in order to avoid this, members of a family, including collaterals, i. e. of a family with a common ancestral origin, often formed themselves into "communities". Besides these family communities, there were other communities composed of people whose only relationship with each other was the fact that they had lived and eaten together for a year and a day, which fact was accepted as proof that they had pooled their belongings, thus complying with the essential principle of a community. These communities often became very powerful, deriving their power from the fact that, in the historical conditions then

obtaining, they could farm on progressive lines and thus draw more from the land than individual tenants could.

It is impossible to draw any general conclusion from the economic and social order characterized by individual ownership of land, because that type of ownership was not established solely for the advantage of the proprietor who worked with his own hand, helped mainly by his own family. Over vast parts of the globe many large, even huge, estates, covering considerable areas and comprising several enterprises, have been established. This has gone on in Europe as a whole since the days of feudalism, but in Italy it goes right back to antiquity. In the underdeveloped countries, however, it is the result of capitalism. These large estates always go in for extensive farming, and often confine themselves to a single crop (coffee, sugar-cane, cotton etc.). Nowadays they are seldom interested in producing foodstuffs, for their aim is to draw as large a net income as possible from the soil or to derive immediate profits from a speculative crop, regardless of the maintenance of the fertility of the soil. This system used to be prevalent in central Europe and the Baltic countries, and is still so in Italy and Spain. It exists also in the more thinly populated of the underdeveloped countries, such as Central and South America, Australia, and so on. It does not provide enough food for the people of the country in which it prevails.

It would be a mistake, though, to suggest that backward agriculture or practices which destroy the fertility of the soil, occur only under capitalist large scale private ownership of the land, for tribal ownership, especially among nomad or semi-nomad people, as in Africa, and even communal ownership among a settled people, as in Madagascar, may lead to the same results.

Summing up, it may be stated that individual ownership and individual farming are not strictly linked to progressive agriculture. Their advantages are relative and dependent on historic conditions. Technical, economic and general social conditions, sometimes even local circumstances, modify their effects. Thus in the mountains, where conditions for agriculture are hard, one often finds, even in advanced countries, survivals of communal regimes which are several hundred years old, and sometimes actual communities, very much alive. High-altitude pastures, in the Alps and the Pyrenees, for example, are, even today, owned and used communally, and this kind of exploitation yields excellent results.

Seen against the background of history, from a social and legal point of view, the ownership of land by individuals appears as accidental. For in history the most persistent form of man's ownership of the land is governed by two concepts: that of *property*, which carries with it the right of disposal: and that of *effective possession*, which carries with it the right of usage. These concepts had, respectively, as their equivalents in the Middle Ages, *supreme dominion*, which the Lords had usually gradually usurped from the primitive community, and the practical dominion of the tenant, which was permanent, subject to the conditions already described.

The future evolution of landed property

At the present time land reform measures to break up the big estates and make their land the property of those who work it are in progress in most parts of the capitalist world. These measures are along two converging lines, of which the first, which is above all social, aims at breaking up the big estates into independent small-holdings, while the second, which is above all technical, collects these small-holdings together to form larger units or lots, ostensibly with a view to facilitate their working. The first disintegrates the large estates, while the second re-integrates them, and is actually called re-integration.

These two reforms lead to more or less the same result: the constitution of small and medium-sized agricultural holdings. There is a difference between them, however, in the fact that, whereas the former (disintegration) benefits only the working land-holder, the latter (re-integration) benefits all land-holders, whether working or not. As the result of this the structure which emerges from the former is much more rigid than that which emerges from the latter. The former, moreover, allocates holdings of definite size and structure, which are in principle invariable, to families which vary in size at various times.

In this way the quasi-permanent disequilibrium between the area to be exploited and the means available for its exploitation becomes aggravated, for the means available for individual agricultural exploitation, of which the most important is generally the family manpower, is in accordance with the area to be exploited only during two short periods: when the children in the family are small, and when the family loses strength by the departure of the grown-up children. There is a similar disequilibrium between the needs of the family and the size of the family holding, and this explains why, in France, the system of family allocations has been extended to agricultural holdings.

Under a system of individual capitalist ownership of land, therefore, the term "family holding" is never more than a temporary reality, on which it is impossible to base a progressive agricultural system and a progressive agricultural economy. For, to make family exploitation a reality, the cultivated land must be raised either by allocation or by sale, in accordance with the size of the family by some means which excludes profiteering. This means that land distribution must be strictly in accordance with the size of the family, as under the communal system.

That does not mean, however, that this is the only way in which cultivable land can be used to the best advantage for meeting the growing needs of mankind. To meet those needs, agricultural production must be increased forthwith, and this cannot be achieved without mechanization. Does this mean that the size of holdings must be increased to the optimum made possible by mechanization, i. e. by the tractor, as has been the tendency during recent decades? It would be rash to say, Yes, to this. For though it

is true that the invention of the horse-collar and the horse-shoe considerably upset both the agrarian structure and the social order of the day, the consequent improvement of horse-traction, though great, did not bring about such a great change in the speed of agricultural work as the tractor has done. Moreover, the latter, by making it possible to dispense with draught animals, has produced an effect which may prove serious, for the maintenance and improvement of the fertility of the soil calls for the use of natural manure, for which a reliable substitute has yet to be found. In order to secure this natural manure, animals must be kept in stables, at least during part of the year, and this necessity has made it possible to observe that, to maintain a proper balance on a farm, the stables should not exceed a certain size (40 to 60 milch cows, for example), or the animals will not be well enough looked after, the manure will become inferior, and its transport to the field will become too onerous a task.

What is required in the future, therefore, is a flexible organization of agrarian systems such as may be realized simply by having a periodical, collective redistribution of the right to use arable land based on its constitution of a working unit (agricultural grouping), instead of on its splitting up or re-integration solely on grounds of ownership (re-integration of property).

There is no reason why one should not consider also the idea of re-integration of land actually worked on a communal basis, either directly by the owners, or by the farmers or croppers. There has been a tendency to do this in France since the end of the second World War. Within these communities which naturally embody the ancient kinds of association, as occurs in the kibutsins in Israel, members may specialize, and may also study, since they have more leisure, and may thus increase their production with less trouble than if they were working as individuals. There is no need for proletarian labour. A final, and extreme, measure is simply to expropriate the land and hand it over to co-operatives for exploitation.

In any case, the problem of the distribution of land so as to secure its better utilization is one which calls urgently for solution everywhere, whether the land has been used for centuries mainly for the production of foodstuffs, or has been ravaged by monoculture or by primitive agriculture based on the burning of vegetation, both of which ruin the soil. In every country collective farming will become more and more necessary for the production of the goods needed by an increasing human population. As early as 1940, Great Britain found herself obligeed to adopt regulations in this connexion which were really revolutionary. The County Committees then set up, and which are still functioning, insist on the farmers achieving a certain minimum production, on pain of expulsion from their farms. In the U.S.S.R., the production of the *kolkhozy* has recently had to be stimulated still more. Although in some countries one finds apparent over-production in agriculture, this is due largely to under-consumption, and there are other countries where chronic and acute hunger

has not disappeared. Physiological needs far greater than the needs of solvency cannot be met for lack of purchasing power. There is a growing disequilibrium between production and consumption.

The most urgent thing, of course, is to adjust international relations so as to cure this disequilibrium. But this must not be done in such a way as to place the peasants in unfavourable economic conditions, otherwise the situation would be made worse. As a matter of fact, it is the countries with an essentially agrarian economy which suffer most from undernourishment. As far back as 1943, the inter-Allied conference at Hot Springs, attended by the representatives of 44 nations declared: "*It is the duty of every nation to see that its population has the foods necessary for its life and health*".

In conclusion, it must be stated bluntly that the problem of adjusting agrarian structures is further complicated by the rivalry between agriculture and industry, to which I first drew attention in 1940, and of which the capital importance was emphasized by Stalin in 1952, when he wrote: "*This problem has not been raised in the classics of Marxism. It is a new problem, raised by our practical experience in the building of Socialism . . . it cannot be said that this problem is absolutely imaginary. It is an extremely serious problem for us*". ("*The Economic Problems of Socialism in the U.S.S.R., 1952*).

The problem became apparent in the U.S.S.R. in the course of its industrial development, but it is present in every country. It is one which is universal and which dominates the whole economy of the world. It is constantly recurrent in ever growing force, and Bergson forecast a solution for it when he wrote, comparing the use of machinery in industry and agriculture, respectively: "*Here, as elsewhere, it is to be desired that there should be a central organizing mind to co-ordinate industry and agriculture*". ("*The Two Sources of Morality and Religion*").

I do not propose to go too deeply into this question, but will simply state that the co-ordination of industry with agriculture means subjecting industry to the pace of agriculture. The only ways in which to do this, it seems to me, would be to have everyone working alternately in industry and agriculture, or else to divide the working members of every family between the two industries, working at different speeds. This would mean a standardization of conditions for the worker-peasant, though there would still, of course, be small differences resulting from specialization, the grading of work, the conditions, and economic circumstances.

The problem of organizing farmland is, therefore, complicated by a new factor which dominates all others in relation to the agrarian structure and system. How will this factor express itself in each country? What will be its evolution? How will it be affected by the intervention of the public authorities? There can be no precise answers to these questions. All that we can see is that in every country in the world the problem of establishing internal equilibrium in agriculture cannot be treated in isolation from that

of establishing dynamic equilibrium in the relations between agriculture and industry. If an effective solution to these associated problems is to be achieved, we must start already preparing for the dispersion of town workers over the rural areas, by making the agrarian system more flexible and by dividing up the land with a view to its utilization to the best purpose. To this end, the collective should exercise more and more rights similar to the "supreme dominion" of the Middle Ages, leaving to subordinate units, such as the family or the co-operative, the "practical dominion", as mentioned earlier, in England.

In any case, the meaning and status of property must evolve, losing more and more its individualistic unlimited and irresponsible character, on which capitalism is based, to resume the personal character which alone makes it possible to keep a fair balance of everyone's rights and duties.

HOW NEW CHINA INCREASES HER GRAIN PRODUCTION

by Dr. Yang Hsien-tung,
President of the Agricultural Association of China

China has been an ancient agricultural country with more than 500 million industrious peasants and an area covering one fifteenth of the land of the world. Nevertheless, old China was a country of famines. At the time when the country was liberated in 1949, the total grain output for the year was only 108 080 000 tons. In the pre-liberation days, even the highest annual production of grain in history (1936) was only 150 000 000 tons.

After liberation, owing to the realization of land reform, the development of agricultural co-operation and the adoption of a series of technical improvements and other effective measures, tremendous changes have taken place in grain production. In the course of seven years, the total grain output has increased every year, from 108 080 000 tons in 1949 to 182 500 000 tons in 1956, which was 68·7 per cent higher than that of 1949, showing an increase of 38·8 per cent over the highest figure before the war (1936) and exceeding the plan of 1957, the last year of the First Year Plan.

The above-mentioned facts reflect the great struggle of the broad peasant masses for the development of production, vividly testifying to the truth of economic science: that only when the labouring people are emancipated from all economic and political bondages can social production power be fully enhanced, and that only when relations of production keep pace with the character of productive forces can the development of production be fully ensured.

Now, I have the pleasure to introduce to you a general outline about the question of grain production of China as related to the system of land ownership and to the development of agricultural co-operation.

1. *Feudal land system kept grain production in bondage*

The social character of China before liberation was semi-feudal and semi-colonial. In the course of the expansion and penetration of imperialist influences into the rural economy of old China, the foundation of feudal exploitation — exploitation of the peasants by the landlord class — was fundamentally preserved. A great part of the land, as the most fundamental means of production in agriculture, was usurped by a few landlords who did not engage in agricultural production.

The distribution of land in old China was extremely irrational. Generally speaking, the landlords and rich peasants who did not form one-tenth of the rural population owned about 70 per cent of land in the rural communities; while the poor peasants, hired labourers and middle-class peasants

together, who composed 90 per cent of the rural population, owned only about 30 per cent of the land. Most of the peasants earned their living entirely or partially by tenant farming. But they were the chief grain producers in old China.

The landlord class in China practised severe feudal exploitation of the peasants. Rent in kind, which was the dominant form of rent, was generally more than 50 per cent of the total output per year, in some cases this being as high as 70 to 80 per cent. The cash rent which was prevailing in some regions was, as a rule, 12 to 15 per cent of the price of the land per year, and in some cases this was as high as 20 per cent. It is estimated that in old China at least some 30 000 000 tons of grain (about 50 to 80 per cent of the total grain obtained by the peasants of the whole country) was robbed annually by the landlord class in the form of rents. These high rents not only robbed the peasants of a part of the products of their surplus labour, but also of a portion of the products of their essential labour. For instance, before liberation, in Chiangchiachiao village, Meitsun district, Wusi county, Kiangsu province, the average costs of production for a peasant to cultivate one mou of land (one mou $= {}^{1}/_{15}$ hectare) were about 56 kg of rice; while his living expenses were about 42 kg of rice. But the annual output of this one mou of land was only 165 kg of rice. After deducting the costs of production and the living expenses above-mentioned, only 67 kg were left. However, the peasant had to pay 50 per cent of his output, or 82·5 kg of rice per mou for rent as designated by the landlords. Accordingly, there was a deficit of 15·5 kg of rice after the rent was paid. This deficit had to be drawn from the costs of the necessities of life or from the reserve funds. Thus the peasants could not but reduce their livelihood to an extremely low level (Table I).

Table I. Average Income and Expenditure for each mou (${}^{1}/_{15}$ hectare) of land at Chiangchiachiao village, Meitsun district, Wusi county, Kiangsu province.
Unit: Rice in kg per mou

Income	Item	Expenditure
—	Cost of production	56·0
—	Living Expenses	42·0
—	Land rent	82·5
165	Total output	—
165	Total	180·5
—	Balance	— 15·5

The landlords had never been known to miss any opportunity to exploit the peasants. Even when the peasants made certain improvements in production, such as reclaiming some wasteland, setting up some irrigation facilities, or improving the soils, the landlords would be certain to increase the rent correspondingly, until the peasants lost their fruit of labour, even when there was a bumper harvest. Thus the enthusiasm of the peasants for cultivation and technical improvements was destroyed.

The irrational feudal land system not only made grain production unstable, but also made the proportion of marketable grain very low, and therefore old China continued to have insufficient grain for a long period. For instance, in 1932, the value of imported rice was the biggest item in the values of imported goods. The same was true in 1933, 1934 and 1935.

2. *Land reform stimulates the development of grain production*

After the founding of New China in 1949, the Government understood very well that the backwardness in agricultural production in the past was precisely the result of the feudal land system. In June 1950, the Government promulgated the Land Reform Law, and the fondest dream of millions of Chinese peasants came true. The main feature of land reform is the confiscation of the land of the landlord class, for distribution among the landless and landpoor peasants, and to transform the feudal land ownership into peasant land ownership. Land reform not only abolished forever the irrational system of land ownership and liberated the great masses of landless and landpoor peasants from the oppression and exploitation of landlords, but, what is more important, also created favourable conditions for the development of agricultural production.

Land reform was basically completed in the spring of 1953. The transformation of the system of land ownership brought great advantages to the peasants. About 300 million landless and landpoor peasants in the whole country, representing 60 to 70 per cent of the whole rural population, received about 47 million hectares of land and appropriated the rents of more than 30 million tons of grain which previously had had to be given to the landlords every year. As well, those who thus obtained land, as a rule, received houses, draught animals and some grain.

As a result of land reform, the principle of "Land to the Tillers" was realized and peasants no longer pay rent. Thus the proportion of their investments for production increased each year and their means of production gradually began to suffice. All these changes have laid the material foundation for the further expansion of cultivation and enhanced the productive force of the rural communities.

The continuing improvement of productive forces in the rural communities greatly stimulated the enthusiasm of the peasants in the improvement of their production techniques. After land reform, the people's governments

at all levels established a number of agricultural organizations, field technical stations, leading the peasants to fulfil the "Patriotic Increasing Production Movements", designed for the promoting of techniques and the raising of production. Millions upon millions of peasants have adopted the new farming methods and raised the output of grains and other crops. Advanced agricultural techniques, such as good-quality seeds, deep ploughing, close planting, applying more manure to the land, preventing plant diseases and insect pests and so forth have been widely adopted throughout the country. These techniques have played an important part in raising yield of grains per unit area.

As a result of the completion of land reform, together with the improvements adopted by the peasants and the increase of productive investments, grain production in the country has come to show gradual advancements. In 1952, the total grain output for the country had already reached the target of 163 900 000 tons which surpassed any previous record, and in 1953, the total grain output reached 166 800 000 tons.

3. *Agricultural production co-operation is the fundamental path to increase grain output*

After the completion of land reform, the agricultural co-operation movement has been developed systematically step by step throughout the country. It is the fundamental way for further advances in agricultural production and for increasing grain output. It is also the way for the peasants to get rid of poverty and exploitation forever for the betterment of their livelihood and the achievement of common prosperity.

The organizational forms for the development of the agricultural co-operation movement in China are mutual-aid teams and agricultural producers' co-operatives.

Mutual-aid teams are peasants' organizations for collective labour and mutual aid, organized on the basis of individual economy, that is, of the peasants' private ownership of land and other means of production. After joining a mutual-aid team, the members have a free hand to use their own land as they wish, but field work is conducted in mutual-aid form, temporary or year round, by members of the whole team. Mutual aid of this type overcomes the difficulties of the insufficiency of labour, draught animals and farm implements. This form of agricultural co-operation was developed on a large scale before 1954. The crop yield per unit area attained by mutual-aid teams is generally higher than that of the individual peasants. According to the surveys of ten villages in the three provinces of Kiangsi, Hupei and Hunan, the peasants who joined the mutual-aid teams in 1953 overcame certain difficulties of individual peasant production and successfully raised their labour productivity, as they were organized, helped each other and worked collectivelly. Therefore their average output (rice, miscellaneous grains etc.) per hectare reached 1 410 kg. while the output

of the individual peasants "working on their own" was only 3 307 kg, i. e. an improvement of 33 per cent.

The agricultural producers' co-operatives are the collective organizations of the labouring peasants, organized on a voluntary basis and for mutual benefit. They collectively make use of the chief means of production of the co-operative members, such as land, draught animals, farm implements and so forth, gradually transforming the private ownership of these means of production into collective ownership. They organize their members to carry out collective labour and the fruit of the collective labour is distributed among the members.

There are two types of agricultural producers' co-operatives: elementary and advanced. During the elementary stage, the co-operative has a part of the means of production, owned jointly by the members, making use of the land, labour and means of production in a unified manner. Members of the co-operative still retain their private ownership of land, collecting a certain portion of the earnings according to the land they pool. This kind of agricultural producers' co-op is of a semi-socialist character. In the advanced type of co-op (equivalent to the collective farm in the Soviet Union) which is entirely socialist in character, the land of the members and other means of production have passed to collective ownership. This kind of advanced type of co-operative is greatly superior. It is able greatly to emancipate the productive force in the rural community, stimulating the enthusiasm and initiative of the peasants and increasing the labour attendance and the labour productivity of the farmers. Besides, this advanced type of co-operative possesses the conditions and potentialities to carry out productive undertakings which individual peasants never dared to do or even to think of in the past.

Following the completion of land reform and the extensive development of mutual-aid teams, agricultural producers' co-operatives began to be organized in one group after another. In the autumn of 1955, there made its appearance the great upsurge of agricultural co-operation movement on a nation-wide scale. Since the autumn of 1955, there has been a fundamental change in the rural community, and socialist collective economy of agriculture has almost entirely displaced the old individual peasant economy. According to the latest statistics, over 93 per cent of the peasant households in the entire country have joined the advanced type of agricultural producers' co-operatives.

The basic change in the relation of production resulting from the co-operation of agriculture has opened up excellent spheres for the carrying out of water conservancy projects, improvements of farming techniques and a series of other measures for increasing grain production.

Following the development of agricultural co-operation together with the continuous state aids, outstanding achievements have been made in the field of water conservancy projects. From 1949 to 1955, the irrigated area in the country was increased by more than 5 800 000 hectares, and more than

24 000 000 hectares of irrigated lands were improved. In 1956, the water conservancy projects completed had enlarged the irrigated area by 6 700 000 hectares. This figure exceeded the achievements of the above-mentioned six-year period following liberation, and also exceeded one-third of the total irrigated area of old China. The extending of irrigated areas by converting dry land into irrigated fields by the agricultural producers' co-operatives and the Government has come to play an important role in the increase of grain production.

The agricultural mutual-aid and co-operative organizations have shown their superiority in the improvement of agricultural techniques. From 1953 to 1955 the total area in the entire country planted with good-quality grain seeds was increased from approximately 10 million hectares to 49 772 400 hactares, an increase of 397 per cent. With regard to the accumulation of farm manures, the agricultural producers' co-operatives in the various places have been extending the movement to increase the storing of composts. In Hopei province, where all the co-operatives have passed on to the advanced type, the total quantity of composts stored by the province as a whole in the spring of 1956 was 29 300 000 tons, exceeding the total quantity of 1954 by 200 per cent. This means correspondingly raising the fertility of the soil. In the agricultural producers' co-operatives, the joining up of the lands and the unified allotment of labour power have created conditions for the change of the system of cultivation.

In the last few years, on the basis of the agricultural co-operation movement, the peasants have made immense improvements both in the control of plants diseases and insect pests. Modern implements and insecticides are widely used and aeroplanes are partly used in the country for the prevention of plant diseases and insect pests. In 1956, about 1 850 000 sprayers with 140 thousand tons of insecticides were used by the agricultural producers' co-operatives and the areas, in which measures for the prevention of plant diseases and insect pests were carried out, totalled 30 million hectares. The locust, which has caused great damage to China's crops for more than 2 600 years, has been largely brought under control and its menace to crops has been greatly reduced. This is something which had never been done in old China.

The new-type farm implements are being widely used by the agricultural producers' co-operatives. In 1956 alone, 1 070 000 double-wheel-double-bottom ploughs were introduced. At the same time as the development of agricultural co-operation, there were, up to 1956, 540 state farms with 325 machinery and tractor stations, possesing 9 603·4 standard 15 h. p. tractors in the country. These state farms and tractor stations, together with the new type farm implements, no doubt, have played a definite part in helping the peasants to improve their farming techniques and increase their grain output and in the gradual realization of mechanized farming.

The economic assistance from the Government to the peasants also has played a tremendous part in the development of their production. From

1950 to 1955, the Chinese Agricultural Bank issued agricultural loans totalling 4 800 million yuan (equivalent to US $ 2 400 m.) on credit. In 1956, the agricultural loans were greatly increased. Up to the end of November, 3 200 m. yuan (equivalent to US $ 1 600 m.) of agricultural loans were issued. These loans were mainly used as foundations of the members of the co-operatives as well as productive loans, which enabled the peasants to carry out different kinds of capital construction, to purchase improved seeds, draught animals, improved farm implements, insecticides and sprayers and other materials for production and to undertake a number of technical reforms. Furthermore, the Government from 1950 to 1956 made an investment of 3 770 m. yuan on river conservancy, irrigation and drainage projects, and issued 1 310 m. yuan on relief work. All these funds had created vital material conditions for the increase of grain production.

The Government has undertaken a programme of scientific research and agricultural education. Before liberation, there were very few agricultural research organizations. The agricultural scientific workers then were not in a position to undertake research work as they wished. Many of them even had to change their occupations or became unemployed. Since liberation, ten regional agricultural research institutes have been set up according to different climatic and soil conditions in different parts of the country. Each province has its own agricultural research institute or central experimental station together with several branch stations. Recently, the Chinese Academy of Agricultural Science, the headquarters of agricultural research, has been organized and a number of fundamental research institutes, such as Plant Science, Plant Protection, Soils and Fertilizers, Animal Husbandry, Agricultural Economics, will be established in the very near future. Since the Government has been paying great attention to agricultural research work, a strong scientific corps has been organized in Chinese agriculture. The conditions of the agricultural scientific workers who could not carry on their research work according to their own lines have been entirely changed. Those who had to change their occupations in the past have all come back enthusiastically to their posts of agricultural research and application.

While agricultural research work has been developed, a remarkable progress has also been made in agricultural education. At present, one agricultural college has been established in each province, except Tsinghai province, and some provinces have two agricultural colleges. The number of students in agricultural colleges in 1956 was increased by 307 per cent, compared with 1949. Agricultural technical schools of middle grade have been established widely in different parts of each province. Up to 1956, the number of students in middle agricultural technical schools in the country were increased by 486 per cent, compared with 1949. In six years, 17 thousand college graduates and 49 thousand middle agricultural school graduates were trained in the above schools. Also, in 1956, 349 agriculture co-operative cadre schools were established in various places in the country.

with 1 354 thousand students. Owing to the development of agricultural science and agricultural education, the assistance to agricultural producers' co-operatives and the guidance in modern agricultural techniques have been greatly strengthened. This is one of the fundamental measures for the raising of grain production in new China.

Facts of the past several years prove that increase of grain production is assured when the peasants take the road of agricultural co-operation. This can be illustrated quite clearly by the Ken Chang-so Agricultural Producers' Co-op in Jaoyang county (an old revolutionary foundation), Hopeh province. (Table II).

Table II. Grain Production in Ken Chang-so Agricultural Producers' Co-op, 1943—1955

Year	Output of grain per hectare (quintal)	Percentage increase	Type of farm then
1943	1 125	100	Individual
1944	1 500	133	Elementary co-op
1949	2 235	199	Elementary co-op
1954	2 528	225	Elementary co-op
1955	3 180	283	Advanced co-op

In 1955, according to the survey of the production of early rice of 6 806 co-operatives in Chekiang province: 2 712 co-operatives effected increases of less than 10 per cent over the average production per unit in that locality; 2 448 co-operatives effected increases of 10 to 20 per cent; 941 co-operatives effected increase of 20 to 30 per cent, and 705 co-operatives effected increase of over 30 per cent. At the same time, a great number of units of particularly high yields, exceeding 6·3 to 14·5 times the national average yield unit area, have continuously made their appearance in various parts of the country (Table III). These high yielding units have thus set up good examples for further increases in grain yieldings, demonstrating the great potential for increase of grain production of the agricultural producers' co-operatives.

Above all, the superiority of agricultural co-operation has been proved by the fact that both grain production and the income of peasants have been increased. Although 1956 was a year of great natural disasters, the grain production was much higher than that of the bumper year 1955. (Table IV).

Such a rapid increase in grain production, so far as I know, has never happened in any other country in the world. The income of most of the peasants in 1956 was above that of 1955, and three quarters of the members

Table III. Models of High Yielding Co-operatives in 1956

Locality	Name of Co-op	Crop	Average output (kg/hectare)	Percentage increase above national average yield
Chen county, Kans uprovince . .	Loo-lu Co-op	spring corn	9 338	600
Puyang county, Honan province .	Sin-hui Co-op	sweet potato	85 110	1 364
Swatow county, Kwangtung province	Hung-kwang Co-op	rice	16 125	63
Weinan county, Shensi province . .	Ho-ping Co-op	wheat	8 985	898

Table IV. Percentage Increase in the Total Output and Per Unit Area Output of Grain in China, 1949—1955

Year	Total Output (%)	Per Unit Area Output (%)
1949	100·0	100·0
1950	115·4	111·8
1951	124·9	118·7
1952	142·8	129·3
1953	145·2	129·1
1954	148·4	129·7
1955	161·7	138·9
1956	168·7	138·1

Note: Owing to great floods, no increase in per unit area output in 1953, 1954 and 1956.

of the agricultural producers' co-operatives of the country, except in the areas suffering floods etc., had increased their income.

The purchasing power of the 500 million peasants in 1956 was increased by 136 per cent in comparison with that of 1950. Such a rapid increase of purchasing power of the farmers had never occurred in old China. The days when the peasant had to subsist on chaff and wild vegetables for six months in a year, have gone forever.

At present, the grain production of China is sufficient to meet the people's requirements, but is still not really bounteous, nor are the Chinese people

satisfied with this production as long as the livelihood of the people is not yet really good. There are still some problems in grain production which need to be solved by constant efforts.

4. Future plans and measures for increasing grain production

With the continuous development of the agricultural co-operation movement throughout the country, the enthusiasm for work on the part of the peasants and their growing demands for better material and cultural life a target for the long-term struggle for production is urgently needed. For this purpose, a "Draft Programme for Agricultural Development in the People's Republic of China, 1956—1967", centred on the development of agricultural co-operation and agricultural production, was proposed at the beginning of 1956. On the foundation of agricultural co-operation, this programme urges the rapid development of agricultural production, forestry, live-stocks, fishery etc. In particular, it proposes that, in 12 years, the average annual yield of grain per hectare in different parts of the country be raised as follows:

1. In the area north of the Yellow River to the north frontier of the country, from 1 125 kg per hectare in 1955 to 3 000 kilograms in 1967, showing an increase of 167 per cent.

2. In the area south of the Yellow River and north of the Huai River, from 1 560 kg per hectare in 1955 to 3 750 kg in 1967 showing an increase of 140 per cent.

3. In the area south of the Huai River to the southern frontier of the country, from 3 000 kg per hectare in 1955 to 6 000 kg in 1967, showing an increase of 100 per cent.

In 1967, the grain output will reach an average of 500 to 600 kg per person. (The increase of population during the same period being taken into account).

The Draft Programme for Agricultural Development in the People's Republic of China 1956—1967, outlines the broad aims of the Chinese people for solving the problem of grain production. The conditions for its materialization are available.

First of all, there are enough hard-working peasants in China. Their potentialities of labour power and of land for the increase of production are very great. The climatic conditions are favourable for grain production. We can grow 2 to 3 crops a year in the same field in many parts of the country. In particular, productive force is being further released through agricultural co-operation of the advanced type. This will no doubt further inspire the astonishing labour enthusiasm and initiative of the great masses of peasants in the co-operatives.

Secondly, in the course of these twelve years, the Government is going to complete many large-scale water conservancy projects and numerous small-

scale water conservancy projects. The area of irrigated land will therefore be greatly increased. In twelve years, all the denuded mountains and barren lands which can be afforested will be afforested, and the calamities from soil erosion will virtually be eliminated. Moreover, according to the Draft Programme for Agricultural Development, 1956—1967, the most serious plant diseases and insect pests are to be virtually eliminated in 7 —12 years. All of these will greatly reduce the threats of the natural calamities to farm crops.

Thirdly, on the basis of agricultural co-operation, technical measures such as the expanding of double cropping areas, the widespread use of good seed varieties, the amelioration of soils, the development of soil and water conservation projects and the wide utilization of new farm implements, the improvement of farming methods etc. can be further carried out.

In order to change the backward state of agricultural science, our country has already drawn up a 12-year long-term plan for the development of agricultural science, urging the Chinese agricultural scientists to summarize and extend the farming experiences of the peasants and to learn the advanced scientific techniques of foreign countries. These measures are bound to play an important role in the development of our agricultural science and the assurance of increase in grain production.

Fourthly, following the development of industrialization of the country, the mechanization of agriculture will also be realized gradually. The output of tractors, power pumps, chemical fertilizers, insecticides and the means of applying them will also be increased each year. This will provide favourable conditions for the improvements of farming techniques and the eliminating of crop diseases and insect pests, thus still further increasing the grain yields per unit area.

Fifthly, there are still approximately 100 million hectares of arable lands which are not yet cultivated. Following the development of our industry, transportation and the mechanization of agriculture, the area of land under cultivation will be expanded each year.

Sixthly, the gradual reduction of illiteracy in the countryside (the Government plans to wipe out illiteracy among the middle-aged and the young in the entire country in the next seven years) and the great increase of the number of technicians in the rural communities (the Government plans to train 5—6 million elementary and medium-grade technicians for the agricultural producers' co-operatives in the next twelve years), together with many other measures, are favourable factors for the increase of grain output.

Above all, many examples of high yields of grains in different parts of the country have proved that it is quite possible for the 12-year targets to be achieved. For example 1. in 1956:

In the area north of the Yellow River to the northern frontier, there were six counties in three provinces already exceeding the 12-year target of 3 000 kg per hectare:

County	Province	Avarage yield of grain per hectare (kg)
Changan	Shensi	3 195
Kaoning	Shensi	3 068
Hsienyang	Shensi	3 203
Mosien	Honan	3 068
Kaochen	Hopei	3 008
Chenting	Hopei	3 720

2. In the area south of the Yellow River and to the north of the Huai River, the average yield of grain of one county, that of Huang-sien in Shantung province, was 4 492 kg per hectare, which exceeded the 12-year target of 3 750 kg by 743 kg.

3. In the area south of the Huai River to the southern frontier, there were already ten counties in four provinces exceeding the 12-year target of 6 000 kg per hectare:

County	Province	Average yield of grain per hectare (kg)
Siaokan	Hupei	6 450
Huangpei	Hupei	6 060
Yiliang	Yunaan	6 338
Nunsi	Fukien	8 978
Tsacan	Kwangtung	8 593
Tsaoyang	Kwangtung	7 560
Chiehyang	Kwangtung	7 643
Puning	Kwangtung	7 808
Naou	Kwangtung	7 868
Ouping	Kwangtung	7 080

These typical examples and the records of high yields as shown in Table III, indicate that the levels of annual yields of 3 000, 3 750 and 6 000 kg of grain per hectare, required in 1967 according to the Draft Programme for Agricultural Development 1956—1967, had already been exceeded in 1956.

No doubt, the 12-year targets will only be reached through strenuous efforts, and various difficulties are bound to be met in our work from now on. We, the Chinese agricultural scientists, are nevertheles confident that if we work hard in our scientific work and learn from the experiences of advanced countries, we are certain, alongside with all the peasants in the country, to overcome all difficulties on our road of advance and accomplish successfully our task of increasing the grain production in our country.

NUTRITIONAL EVALUATION OF HIGH CEREAL DIETS*

by

Professor Yang En-fu, China

A scientific investigator in any part of the world whose interest is on nutritional problems, whether he be clinician or laboratory worker, usually pays attention first of all to the food habits and nutritional status of his own country. This is especially true in a country whose modern scientific work has only been lately developed.

Chinese agricultural development reached a high level about four thousand years ago. Cereals and legumes formed the main sources of calories of the people. The ancient Chinese physicians had long recognized that a rational diet should contain cereal, meat, vegetable and fruit.[1] However, with the rapid increase of the population, the diet of the people depended more and more on cereals, and animal food in the diet thus decreased in proportion. Nutritional surveys, past and present, show that 85 per cent of the calories for the majority of the people are derived from cereal. Although the soya bean is a famous product of China, it supplies only slightly more than 10 per cent of the total calories of the diet.

Even in a well-to-do family, which can afford animal food, cereal still is the main source of food energy, being about 70 per cent of the total dietary calories. Cow's milk, the food recommended most by nutritional workers, is consumed in large quantities only by people of a few minority races. For the majority of the people it forms only a negligible part of the diet. When cereal forms a high proportion of a people's diet, rural economists agree that it is impossible for the country to have a large store of food, and any degree of natural calamity may cause famine in one or another section of the population. This was the situation in China before and during the earlier period of liberation. In spite of a great increase in farm production to meet the demand in quantity, it is impossible within the immediate future to reduce the percentage of calories in the diet from cereal. High cereal diet is by no means typical of China only, the survival of more than half of the world's population depending upon this type of diet.

Without resorting to much calculation of nutrients, nutrition workers can recognize at a glance, from the standard of nutrition allowance, that this type of diet is unbalanced. Owing to the shortage of animal food, the quality of the dietary protein is inferior. Insufficiency of cow's milk does not only cause difficulty in meeting the requirements of infants and children, but also fails to satisfy the calcium and riboflavin requirements

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of adults, because about 50 per cent of these two nutrients are derived from dairy products in countries where the milk supply is adequate.

On the other hand, the standard for nutritional allowance proposed by experts in this field is often made by adding a margin of safety to that recognized as the minimum requirement. It is thought that this may cover the possible variations among individuals and external environments. However, there is not sufficient experimental or theoretical evidence for its support. As an example, Rose[2] proposed that optimal requirements of various essential amino acids should be calculated by doubling the minimum requirements, which in their turn were the highest values of the minimum amount of each amino acid needed to maintain the nitrogen equilibrium of his experimental subjects.

There is no way to prove the soundness of this method. Furthermore, owing to the difference in criterion employed in the estimation of the minimum requirement, the value obtained also differs. Thus there is a great deal of difference in the standards of nutritional allowance as well as minimum requirements adopted by nutritional workers in different countries, which may also give rise to a different interpretation in evaluating the nutritional function of a certain type of diet. This is especially true for high cereal diet. However, more scientific investigation is needed for a final decision. With the advancement of the science of nutrition, the nutritional evaluation of a diet may be altered. In this report, an attempt will be made to give a brief summary of the work related to this problem by my Chinese colleagues.

Protein nutrition

It has been frequently accepted that the most serious defect of a high cereal diet is the low nutritional value of vegetable protein. This statement has been supported by the determination of the biological value of vegetable protein with animal or human subjects. The results of essential amino-acid analysis also indicate the unbalanced nature of amino acids in protein from this source in comparison with that from animal foodstuffs[3]. Cereal proteins are especially low in their contents of methionine and lysine. However, in evaluating the protein nutrition of a diet, it is not only the quality, but also the quantity that should be considered. In the estimation of the biological value of a protein, the protein content of the diet is usually kept below the minimum requirement of the experimental subject, for otherwise, the expected value cannot be obtained.

Hegsted *et al.*[4] found that supplementation of methionine and lysine to a vegetarian diet containing 28 g of protein per day gave a favourable nitrogen balance in human subjects, but not to a diet containing 48 g/day. In fact, when there is no caloric deficiency, a diet with 85 per cent of the calories derived from cereal will maintain nitrogen balance in adults. Under the condition of high cereal diet, an adult with a daily supply of 2 400

calories consumes about 600 g of cereal. The amount of each essential amino acid in this quantity of different cereals is listed in Table I. It can be seen from the table that 600 g of the cereals listed supply a sufficient amount of all essential amino acids except methionine to meet the requirement as recommended by Rose[2] and by Stare *et al.*[5]

The essential amino-acid contents in diet calculated from the result of nutrition surveys (Table II) indicate that methionine is also sufficient to meet Stare's recommendation, with all of the other essential amino acids being two or three times the requirements. With the exception of the experimental diet, the protein from animal sources in all the other diets is less than ten per cent. In spite of the fact that the Japanese consume more animal foodstuffs, the amounts of different essential amino acids obtained from the diet are almost the same.[6] The experimental diet, in which 50 per cent of the total protein is supplied from animal food, gives a somewhat increased amount of methionine and lysine, but there is no apparent change in other amino acids.

Even in a complete vegetarian diet, with 20 per cent of the protein supplied by legumes, though the methionine and lysine contents are somewhat low, they are still sufficient to meet Stare's recommendation. Furthermore, the diet used by Rose for the estimation of the requirement of methionine and cystine was not included. Recently Swendsaid *et al.*[7] estimated the minimum requirement of methionine for women and found it to be 0·12—0·50 g/day lower than the value obtained by Rose. One may conclude, then, that protein in a high cereal diet can adequately satisfy the requirement of essential amino acids of adults.

TABLE I

Essential amino acids in 600 g of cereal and their requirements by adults (g)

	Threonine	Valine	Leucine	Isoleucine	Lysine	Methionine	Phenylalanine	Tryptophane
Rice	1·8	2·5	4·0	1·5	1·8	0·9	2·1	0·7
Millet	2·8	3·2	8·2	2·2	1·4	1·9	3·2	1·2
Corn	2·2	2·4	7·9	1·7	1·9	0·9	2·5	0·4
Kao-Liang	2·3	3·4	10·3	2·4	1·4	1·1	3·4	0·6
Wheat flour (81 % extraction)	2·1	2·8	4·7	2·1	1·7	1·0	3·2	0·7
Adult requirement (Rose)	1·0	1·6	2·2	1·4	1·6	2·2	2·2	0·5
Adult requirement (Stare)	1·2	1·3	3·6	1·3	1·4	1·4	1·4	0·4

TABLE II

Essential amino acids supplied by various diets (g/day)

	Threonine	Valine	Leucine	Isoleucine	Lysine	Methionine	Phenylalanine	Tryptophane
Middle school students	3·6	4·4	9·4	3·2	3·5	1·6	4·3	1·1
College students . . .	3·0	3·6	6·9	3·0	3·3	1·5	3·7	1·0
Workers	3·6	4·4	8·4	3·5	3·6	1·7	4·8	1·2
Experimental vegetarian diet	3·2	3·5	5·8	2·4	3·6	1·4	3·9	1·2
Experimental mixed diet	3·5	4·4	6·2	4·0	4·8	2·3	4·3	1·2
Japanese diet	4 3	3·9	5·7	3·2	3·4	1·7	4·0	1·0
American diet	3·5	3·8	9·1	3·3	5·2	3·8	4·4	1·1
Adult requirement (Rose)	1·0	1·6	2·2	1·4	1·6	2·2	2·2	0·5
Adult requirement (Stare)	1·2	1·3	3·6	1·3	1·4	1·4	1·4	0·4

Mitchell and Block,[8] and Oser[9] made use of the essential amino-acid content for the calculation of the biological value of protein. The practical significance of such a calculation remains to be determined. It has been shown recently that certain amino acids in some vegetable protein may not be available for the animal body. An excess of a certain amino acid in the diet may cause amino-acid imbalance,[10] and thus decrease the rate of growth. So far, we have been unable to find any report on such study with human subjects.

Although it is generally agreed that vegetable protein is less digestible than animal protein, there is still some doubt on the validity of this conclusion. McCance[11] suggested that protein in wheat flour can be completely digested by man. It is rather doubtful whether the result obtained by the usual method for the estimation of the digestibility of protein can represent its true availability. The effect of cellulose on the faecal excretion of nitrogen has been repeatedly recognized by earlier investigators. In a preliminary experiment, we found that different forms of starch may cause a variation in faecal nitrogen excretion and yet did not affect nitrogen retention by the rat.[12] Thus the high excretion of faecal nitrogen during a vegetarian diet may not represent low availability of the protein.

Indian workers, Patwardhan *et al.*,[13] compared the availability of protein in vegetarian and mixed diets. The amount of protein in these two diets were the same, but in the mixed diet 50 per cent of the protein was supplied by animal food. They found that the vegetarian diet caused a higher nitro-

gen retention in their experimental subjects than did the mixed diet. This result has also been confirmed by us.[14] It was found that the favourable effect of the vegetarian diet was also seen on the first two days after switching to the mixed diet. Faecal excretion of nitrogen was slightly higher when the subjects were on a vegetarian diet than when they consumed a mixed diet. The favourable nitrogen balance on a vegetarian diet was due to a low urinary excretion (Table III). From the result obtained by Patwardhan and that by ourselves, we are of the opinion that there is no difference in protein storage in the body whether the diet is completely vegetarian or mixed with animal food. If there is any, it is in favour of the vegetarian diet. At the moment we have not enough experimental evidence to give an explanation of this phenomenon. However, it can be stated that the inferior quality of the protein in high cereal diet does not affect the protein nutrition of adults. Blood examination seems also to support this conclusion. The normal value of plasma protein for normal adults is 6·5—7·5 g/100 ml. Recently, Liang[15] determined the distribution of serum proteins, and there

TABLE III

Nitrogen balance of adults on vegetarian and mixed diets (g per person per day)

	Vegetarian diet	Mixed diet		Vegetarian diet		Mixed diet		Vegetarian	
	Average of last 8 days	Average of first 2 days	Average of last 8 days	Average of first 2 days	Average of last 8 days	Average of first 2 days	Average of last 3 days	Average of first 2 days	Average of last 3 days
Nitrogen intake	13·44	13·65	13·10	13·66	13·74	13·22	13·22	13·06	13·88
Urinary nitrogen	9·69	9·60	10·95	9·46	10·05	10·10	11·55	10·66	10·82
Faecal nitrogen	2·90	2·41	2·41	2·82	2·82	2·33	2·33	2·41	2·41
Nitrogen balance	0·84	− 1·64	− 0·26	1·38	0·87	0·79	− 0·56	− 0·01	0·65

TABLE IV

Percentage distribution of serum proteins in Chinese and American adults

	Chinese	American
Albumin	54.6	60.5
Alpha$_1$-globulin	3.6	4.0
Alpha$_2$-globulin	9.8	7.7
Beta-globulin	16.1	11.5
Gamma-globulin	15.9	12.3

was not much difference between his results and those compiled by Albritton[16] for American adults. (Table IV).

Vitamin nutrition

With the exception of riboflavin and vitamin B_{12}, cereal grain is rich in all other members of the vitamin complex. Of course, an excessive degree of milling may cause a considerable loss of these vitamins, especially vitamin B_1. Since the Chinese government has taken measures to control rice and wheat flour processing, beri beri has become a rare disease in the hospitals of industrial cities (e. g. Shanghai and Canton) of the rice districts. Pernicious anaemia, which is due to vitamin B_{12} deficiency, is also rarely seen in China. The source of this vitamin in the Chinesse diet remains to be explored.

The results of nutrition surveys indicate that the daily intake of riboflavin by Chinese adults is between 0·6—0·8 mg and only in rare cases, it reaches 1·0 mg. Aribоflavinosis, which can be treated with pure vitamin, is frequently seen and loading tests also indicate riboflavin deficiency. However, the majority of the people consuming a similar diet do not show clinical manifestation. No effect on the growth of 13 to 16 year old children could be found with a daily supplement of 1 mg of riboflavin for 1 year.[17] Loading tests indicated that the supplemented children excreted more riboflavin, but the level of the excretion by the unsupplemented children also approached the normal, as claimed in literature, i. e. 20 per cent of the test dose.[18] At present, there is still no proper answer to the question of riboflavin requirement. The factors affecting the development of various clinical manifestations of aribоflavinosis must be investigated further.

Owing to the shortage of dairy products, the main source of vitamin D comes from sunshine. In the warm districts of South China, vitamin D deficiency is not a serious problem. Because of the long indoor life in winter in North China, women and children do not have great exposure to sunlight. The high cereal diet contains a large amount of phytic acid and only a small quantity of calcuim. Rickets and osteomalacia therefore are prevalent nutritional diseases. According to Liu,[19] the main cause of osteomalacia is the lack of vitamin D, while calcium deficiency plays a secondary part. This may explain the high incidence of rickets in North China, since the diet in South China is also deficient in calcium and yet this disease is rarely seen. Recently, a survey of serum alkaline phosphatase of the infants in Peking was made and it was found that about 25 per cent had a level above the normal standard in April, but only 10 per cent in May.[20] While outdoor activity is important for the prevention of osteomalacia and rickets, the supply of vitamin D from dietary source is also an important measure, especially in the northern district.

The daily requirement of vitamin A for the adult, recommended in various countries, is 5 000 I. U. One third of this is to be supplied by animal

food. In fact, this amount of preformed vitamin A is already sufficient to meet the minimum daily requirement. Hence, in a country with an adequate supply of dairy products, the rate of utilization of carotene in vegetables is not an urgent problem. Under the condition of high cereal diet, however, the source of vitamin A depends almost entirely on carotene and thus its efficiency of utilization is of paramount importance in determining vitamin A nutritional status.

Experimental results of the British Medical Research Council [21] indicate the availability of carotene varying between 25 and 80 per cent depending upon the source. Li determined the availability of carotene in the vegetables commonly consumed in Peking and found that the rate of utilization by human subjects was, in most cases, only about 25 per cent.[22] In South China, where green vegetables can be obtained almost throughout the year, it is comparatively easy to satisfy the requirements of this vitamin. However, in the north, the main vegetable available for the winter is celery cabbage (Peking cabbage) which has a very low carotene content. Therefore vitamin A deficiency symptoms such as poor dark adaption, low level of serum vitamin A, and occasional night blindness and follicular keratosis may be seen during nutrition surveys in the spring. Vitamin A deficiency forms one of the defects of high cereal diet especially in the northern district.

Calcium nutrition

Low calcium and high phosphorus contents in high cereal diet forms a special problem in nutrition. Nutrition surveys made both in China and Japan all indicate the daily supply of calcium for adults to be below 0·4 g, and that of phosphorus 1·3 g, in which a large proportion is in the form of phytic acid. In a previous section, it has been mentioned that deficiency of calcium may not be the main cause of osteomalacia and rickets. However, whether this low supply of calcium is adequate or not for human requirements remains to be considered. Nicholls[23] and others suggested that there is an adaptation to low calcium. When the supply of calcium is low, the rate of utilization by the body is increased. It must be noted, however, that this can only apply to the percentage of utilization, and not to the absolute amount of calcium absorbed. When the calcium intake is low, the actual quantity of calcium absorbed remains low.

Aykroyd and Krishnan[24] found an improvement of growth in children consuming high cereal diet was observed by supplementing calcium within two and a half months. We observed the same effect with older children (13—16 years) by supplementing daily 0·5 g of calcium per child for one year.[17] However, no such effect was obtained above that age.

It has been observed by Sherman and his co-workers[25, 26] that high calcium diet may enhance longevity and the rate of reproduction in the rat. However, it is impossible to make a similar observation in man. Besides

nutrition, there are other complex factors which may affect these two biological aspects in man. With the exception of pregnant and lactating women, it is difficult to ascertain any detrimental effect of the low calcium intake resulting from high cereal diet on adults.

Ways of improvement

Modern knowledge of nutrition is still not sufficient to determine the effect of different diets on the health of the people and thus any suggestion of improvement may be inadequate. Or present knowledge of the physiological properties of an individual nutrient and its distribution in food may allow us to recognize the particular effect of a certain diet. On the assumption that the main defect of a high cereal diet is its lack of animal protein, suggestions to increase meat, egg and milk production have often been made. In practice, however, a significant increase in production of these foodstuffs will take a very long period. Among these three types of food, it is comparatively easy to increase meat supply by promoting pig-breeding and fishery. Pork and fish form a good source of animal protein but not that of vitamins and minerals which can be supplied by egg and milk. From the material presented above, the main nutritional problem of a high cereal diet for adults is vitamin and mineral deficiency, and not lack of protein. Increase of meat production may satisfy the people for the enjoyment of food, but cannot solve the nutritional deficiency. Under this condition, the easiest way of improvement is by fortification with pure nutrients such as vitamin B_1, B_2 and A, calcium and iodine.

So far, little has been said about infant nutrition. In a country with inadequate milk supply, the weaning diet of the infant is very similar to that of the adult. It is quite possible that kwashiorkor may also occur in China, but very little of it has been reported to the present time. This may be due to the fact that the disease is not prevalent enough to attract the attention of the pediatrician. Respiratory infection and digestive disturbances which may be related to nutritional deficiency are common diseases among infants. Although infants and children have priority in getting milk in China's large cities, this food is far from sufficient to meet the needs of the whole country. This condition may also be corrected by applying modern knowledge of science to nutrition. On the basis of rice cakes commonly used in Chinese families for infant feeding, Chow[27] made an improved formula by supplementing it with soya bean, egg-yolk, bone meal and riboflavin. An experiment was carried out on one hundred infants for assessing the nutritional value of this milk substitute. The growth rate of the infants was normal, and no digestive disturbance was observed.

In view of the above facts, we believe that with further advances of our knowledge of human nutrition, the existing problem may be solved with foods that can be easily produced rather than waiting for a slow development of animal husbandry, especially dairy products.

Summary

Approximately 85 per cent of the total calories in the Chinese diet is supplied by cereal grains. However, significant reduction of the proportion of cereal in the diet cannot be expected in the near future, in spite of the increased food production recent years. Proper nutritional evaluation of this type of diet is essential in planning ways of improvement.

From the distribution of the essential amino acid in different cereals, the contents of amino acids supplied by different diets, the comparison of nitrogen balance in human subjects on vegetarian and mixed diets and the distribution of serum proteins in normal Chinese adults, the concept that poor quality of vegetable protein forms the main defect in high cereal diets is disputed.

Owing to the shortage of dairy products, deficiency of vitamin A, riboflavin and calcium is the main nutritional problem in the high cereal diet. Increased production in meat cannot correct these defects.

Successful results have been obtained by the use of milk substitutes in infant feeding. This indicates that with further advances in nutritional knowledge, problems resulting from high cereal diets can be solved with fortified foods which can be easily produced.

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VARIETIES OF UNBALANCED DIET AND THEIR EFFECT ON NUTRITION*

by

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Diet is only one of the factors that determine the state of nutrition. Good nutrition is impossible unless the diet is reasonably adequate, but a poor state of nutrition may exist in spite of an adequate diet.

A diet that is unbalanced in its chemical constituents gives rise to a *deficiency disease*. These diseases have been studied extensively and much of the writing now in vogue gives the impression that malnutrition is simply a series of text book pictures of deficiency diseases. Thirty years ago, vitamin deficiencies were the only ones mentioned. Recently it has been recognized that deficiencies can occur in proteins and carbohydrates, and in various minerals, while *diseases of excess* are also identified.

Before the days of biochemistry, it was customary for physicians to make their prescriptions, both of drugs and of nutriments, long and complicated. This was to some degree an insurance against the appearance of iatrogenic deficiency diseases. Now that we have at disposal drugs and nutriments in their pure form, the dangers of producing imbalance have greatly increased. To give concentrated vitamins or large quantities of food to malnourished patients may transform a dangerous into a fatal imbalance. Trowell[1] describes how in 1937, when kwashiorkor was determinedly called "infantile pellagra", he was induced to treat the patients with the newly introduced niacin and "almost all the children died". Other observers have reported how half starved prisoners of war who on liberation demanded an unrestricted supply of bread, became afflicted with severe beri beri, with some fatalities.

There are other dangers lurking in imbalance. Woolam[2] found that rats that were irradiated produced nearly four times as many young with congenital abnormalities if they were fed a high vitamin diet.

But a great deal of attention has been given to chemical and biochemical balance. The larger the supply of carbohydrate, the greater is the need for thiamin. The more rapidly the baby is growing, the more does it need vitamin D to metabolize the calcium and protect against infection. We now have a fair idea of what constitutes an adequate diet. But if we consider the wider fields of nutrition, there are other balances which must be considered without which the chemical and biochemical balance may be upset.

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(a) *Physical properties of diet*

The physical properties of food deserve more consideration than they usually get. Some years ago we used to hear a good deal about "roughage" and the need for large quantities of this to be incorporated in the diet. But in this a balance should be preserved. Some diets contain insufficient roughage and others far too much, especially for children and others with poor digestions. The millets and sorghums, so often lauded by the nutritionists for their protein and mineral content, are often passed almost undigested. Unless these grains are well prepared they retain a great deal of husk and silicaceous material. They must be thoroughly cooked or they act as irritants. In Asia one sees good wheat flour being given to young children as tough chappattis, and producing dyspepsia and other complaints. In some parts of the world root vegetables, maize and bread fruit are roasted hard and become virtually indigestible.

Hipsley has suggested that it is the presence of fibre in the diet that protects certain populations against the toxaemias of pregnancy.[3] Whatever adults may learn to tolerate, it is to my mind quite certain that a great deal of malnutrition that now exists among children is due, not to the lack of food, but to the dyspepsia, diarrhoea and malnutrition resulting from the way in which food is prepared and presented. The balance between "low residue" and "roughage" needs to be adjusted for age groups and for individuals. There is a large mortality from gastroenteritis. Sometimes it is the irritating qualities, and sometimes it is the sheer bulk of the food that have rendered the intestines incompetent, or liable to invasion by pathogens.

(b) *Bacteria, helminths and toxins*

Certain bacteria are necessary for the breakdown of foodstuffs in the intestines and for the synthesis of vitamins. Foy and Kondi[4] have stated that a high carbohydrate and low protein diet is inappropriate for the synthesis of B_{12}. The interaction between the chemical components and the bacteria of the intestine may be a decisive factor in nutrition. Young children are peculiarly liable to attacks of gastroenteritis. Luder[5] found that the classification of cases of diarrhoea and vomiting in children in Uganda is "rather different from that applying in temperate climates". It is probable that this difference in bacteriological content is not merely a result of climate, but of different food and food habits.

The presence of helminths may be another important factor contributing to imbalance. Many doctors, especially those not accustomed to treating children in tropical areas, still persist in believing that hookworms matter and that roundworms do not matter, unless perhaps when they are present in very large numbers. In many regions ankylostomes are relatively rare under the age of 2 years, but they can cause disease. In many coun-

tries roundworms are exceedingly common, and a baby may be infected at any moment after birth. One or two roundworms in the digestive tract of a young child can interfere seriously with digestion and absorption. It is only by careful post mortem examination that the presence of these worms can be diagnosed unfailingly. Tapeworms and strongyloides may also be of grave significance and cause death.

Toxins may be ingested in herbs, leaves, roots and seeds used as food, as infusions and as medicines. Even in the most sophisticated areas there are shops where "simple herbal medicines" can be purchased. In every market place in Africa and Asia, urban and rural, there are purveyors of "native" medicines. Recent work by Dr. R. Schoental[6] has shown how senecio and crotalaria can produce fatty livers in rats and particularly in young and under-nourished rats. Some species of senecio have been used as a medicine, and I have seen crotalaria used in Jamaica as a treatment for scabies. The presence of toxins in food and medicine is yet another factor upsetting nutritional balance.

(c) *Varying demands of age, growth and development, exercise and stress*

It is well known that the growing organism requires more of certain foodstuffs than does the adult. But it is impossible to establish an exact formula of requirements. In the discussion on "Human Protein Requirements and Their Fulfilment in Practice"[7], Holt is quoted as saying that a baby needs ten times as much per kilogram body weight as an adult of each of the amino acids, while Gyorgy referred to other work proving that only one-third to one-fifth of this quantity is necessary. Some workers claimed that B_{12} had a sparing effect on methionine and choline, others that if an animal was short of protein it could obtain its nitrogen from urea. Some observers[8] have found exceedingly high serum proteins in people living on a high carbohydrate diet. In fact there are so many aspects of nutrition that are modified by others that rigid standards are impossible. The only fact of real essential value is the clinical condition of the patient.

It is certain that the most frequent and severe cases of deficiency diseases are those that occur during the period of rapid growth — 6 months to 6 years, a period that is associated with repeated stress and repeated demands for adaptation; a period which is peculiarly liable both to chronic subnutrition and to the more easily identified forms of deficiency diseases which are the result of imbalance.

Beri beri, scurvy, rickets and kwashiorkor may each or all of them occur in large fat babies. Even so these cases may be missed because they are so far from being emaciated that the inexperienced doctor does not associate them with types of malnutrition. The more rapid the growth, the more serious the imbalance and the more acute and serious the disease. Sometimes the child's condition deteriorates with alarming suddenness. Sometimes there is a precipitating factor such as abrupt weaning, an attack

of diarrhoea or an infectious disease such as measles or whooping cough. In countries where malaria and other "tropical" conditions are endemic, these create an additional demand on the protein resources.

Exertion may play a part in determining the occurrence of imbalance. The demands on food made by expenditure of energy show enormous variation. A recent article by Booyens and McCance[9] states "there are always some individuals who have calorie intakes greatly in excess of others, and the differences cannot necessarily be explained by size or obvious muscular activity". They conclude that the limits usually accepted for normal basal rates are far too narrow and a Basal Metabolic Rate 30—35 per cent below the average is not necessarily abnormal. Ability to relax and a highly developed sense of rhythm can save a great deal, not merely of calories, but of total metabolic expenditure.

(d) *Timing*

Nutritionists often assess the adequacy of a diet by total quantities of the various essentials, and are apt to forget how these values can be upset by imbalance in timing.

The small baby needs to be fed at frequent intervals if it is to thrive. A healthy baby is reasonably adaptable and even on a self demand system will often settle down to a more or less regular schedule of 3 or 4 hours. I have seen babies whose mothers spent most of the day away at work. They made up for this by demanding the breast 3 or 4 times during the night, with apparently little inconvenience either to the mother or the child.

It is the weaning period when children are subjected to the worst faults in timing, and as toddlers they may get very little to eat until the evening meal. Then one sees examples of pot bellies, spindle legs, of chronic dyspepsia, alternating bouts of diarrhoea and constipation, the distension which produces atonic intestines and all too frequent abdominal crises. In other families you may find the children who are given snacks all day long. Very often their appetites become disordered and their digestion inefficient.

In many countries it is found that children who go to school have a 5-mile walk, a day in school, and a walk home again with little or no food. This is one of the great arguments for the provision of school lunches — often a difficult and expensive solution. The reasons behind malnutrition in school children are many and various. Sometimes it is poverty and food shortage. Sometimes it is lack of imagination and understanding on the part of the parents. It may be that children are given money for food but spend it all or sweets and aerated waters. In one rural area in Africa where school children were advised to bring lunch with them, they retorted "We are not labourers. We cannot possibly *carry* anything". Recently I was told about a girl of 18 working in a London office. The total family income was over £50 a week, but the mother never got up in time to give them breakfast. This girl would not prepare any food herself "because she would then be

expected to prepare breakfast for the two school children as well". She preferred to feel famished until the lunch break at the office.

As well as these daily indiscretions in timing of food, we find particularly in the more backward areas a very marked seasonal variation. To some extent this is due to storage difficulties, but it is also caused by a marked preference for the occasional gargantuan feasts and festivals with intermediate periods of great austerity.

Whatever may be the cause it is obvious that adults can train themselves to vastly differing patterns of food consumption without necessarily causing much distress. But for young children and adolescents, imbalance in timing may be damaging and even fatal.

(e) *Habituation and psychological aspects*

Acceptability and digestibility of food largely depends on habituation. There are many examples of this. People who are conservative and monotonous in their food habits are intolerant, emotionally and physiologically, of strange foodstuffs.

Health education should encourage a varied diet, so that the digestive system becomes receptive to a wide variety of foods. This would help to prevent imbalance and would lead to a more elastic and efficient nutritional economy.

The digestibility of food largely depends on the psychological attitude with which it is approached. Fear may give rise to vomiting and diarrhoea, but there are many other stages of digestive troubles caused by a variety of emotions.

(f) *Individual variations*

Food allergies are well known. They appear to be far more common in "well fed", sophisticated communities than they are in the less well nourished. Like diabetes, hypertension, peptic ulcers and obesity, they appear to be among the penalties of "civilization". There are other idiosyncrasies with regard to food that make it essential for nutritional problems to be studied on an individual and not merely on a community basis. The rarer metabolic diseases are already being exhaustively studied. It is quite obvious even from macroscopic inspection of stools that individuals vary, and each individual varies from time to time in ability to digest and absorb. The article already quoted by Booyens and McCance gives an idea of the wide variation in metabolic rates in adults.

The effect on populations

It is quite impossible to assess the effects of unbalanced diets on a population unless non-dietetic factors are studied at the same time. Short term surveys are liable to be misleading and there is great need for long term

studies. No survey can be significant unless it weighs all the factors that have led to the nutritional state which it is attempting to appraise.

Comprehensive studies must include the following:

1. Vital statistics, including survival rates in various age groups. Fertility and population trends.

2. Prevalent diseases of every description, dietetic and non-dietetic, and their response to treatment.

3. Customs and beliefs, including those in relation to food and medicine. Social structure.

4. Development and growth of various age groups. Capacity, mental and physical. Ability to adapt.

5. Environmental conditions. Actual and potential food supplies.

Fashions in nutrition are always changing. A few years ago vitamin deficiencies were all important. Recently we have been told that protein deficiency is the most important condition and "you need glucose for instant energy". Now we hear that the saturated fatty acids are the greatest menace to well-being. It has been alleged that great fertility is a sign of protein shortage. But much of our information is incomplete. The reported incidence of kwashiorkor, for instance, depends more than anything else on the incidence of paediatricians. It is not until we have more painstaking and long term observations that conclusions will be of great value.

One article I have found most interesting is by Dr. Mary P. Jackson in an address to the Canadian Medical Women's Association in 1955 called "My Life on the Key River"[10]. It describes the author's 30 years of work in a rapidly changing community. She concludes: "Did my friends of the 1930's live to a vigorous old age because they were always thin? Could it be simply because they are now getting more to eat that my Metis patients suffer from dental caries, toxaemia of pregnancy, diabetes and hypertension? I wish I knew how to find out, for whatever the cause, the result is a tragedy".

Unless we study nutritional problems in their setting, unless we observe the dynamics of a community as well as its status, the result is not one but many tragedies. Too much effort is being put into laboratory work compared with that spent in the field. Our resources in time and personnel are devoted to investigating and discussing analytical and ultra-microscopic details. Comparatively little is being done for the treatment and supervision of malnourished children where this work is most desperately needed.

Nutrition must be studied in man in his environment. It is important that those interested in nutrition should try and establish a more reasonable balance between laboratory and clinical work.

Summary

1. In the past attention has been concentrated on providing diets which are balanced in their chemical and biochemical properties.

2. The dangers of imbalance and over-dosage are increased by the availability of foodstuffs in a pure form, and by failure to recognize the complex aetiology of nutritional diseases in the field.

3. Imbalance may result from factors such as physical properties of the food, the bacteria, helminths and toxins contained in it, the varying demands of metabolism, wrong timing, lack of habituation and to various idiosyncrasies.

4. The effect of food patterns on a population can be assessed only if there is opportunity to study the nondietetic as well as the dietetic disorders and other factors in the environment.

5. There is great need for more clinical work in nutrition. At present the most serious imbalance is the excessive attention given to laboratory findings, with insufficient attention to clinical needs.

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HUNGER AND DISEASE

by

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When attempting to define the concept of "hunger", we encounter certain difficulties, because organisms are able to adapt themselves to environmental conditions, including food intake, provided these conditions act upon them for prolonged periods. Average dietary allowances on which some populations live, would be quite inadequate for others. Despite this fact some of these rations, e. g. those of some Asiatic peoples, are not considered to be on a "starvation level".

De Castro has shown that food consumption figures alone and the fact that certain groups of people exist on a certain intake in a state of semi-starvation, by no means prove that those rations are adequate for the population groups concerned. Under these conditions various pathological states develop (e. g. tropical forms of beriberi, different types of hepatic disease covered under the heading of kwashiorkor etc.) and the population is affected by various well known symptoms of malnutrition.

Apart from these manifest "diseases of hunger" there are, however, latent clinical deficiencies which are more difficult to define because the clinician encounters them in their final stages already as pathological states where the association with nutritional factors has apparently vanished. This leads to a certain lack of confidence of the public and even of some doctors in the importance of nutritional factors for the health of the individual and whole population groups. While infections present within a few days or weeks a clear clinical picture and their etiology can be easily followed, it is difficult to make any definite statements e. g. on the part played by the size of the fat allowance — and maybe its composition — in the development of obesity or atherosclerosis, processes which take years to develop and compel the patient to see the doctor only after the pathological factor has affected certain organs.

The physician is frequently confused by the fact that symptoms regress after various drugs, which help to compensate the pathological functions without altering the nutrition of the patient. This applies e. g. to the well known favourable effect of weight reduction by obese patients on the course of the disease (e. g. in diabetes), while the dietary regime after myocardial infarction and of atherosclerotic patients is still a matter of discussion.

This is the position with diseases where the nutritional factor manifests itself fairly clearly in the defined pathological picture; it is, however, even more difficult to prove the significance of inadequate intake of certain nutrients on the development of secondary phenomena due to subclinical deficiencies of certain factors, the role of which has been elucidated only

by modern biochemistry. I have in mind a group of facultative relative deficiencies of some vitamins or nutrients. Classical beri-beri has taught us to detect even less marked deficiencies of aneurin in some cardiac disturbances or cases of neuritis. This is, however, not the case with all nutrients. We can reasonably assume that — for example — the mass incidence of infectious hepatitis and the increased consumption of alcohol may in many European countries induce a relative deficiency of vitamin A and carotene in many of the patients concerned, while the average vitamin A and carotene allowance of the population as a whole may still be adequate. The mechanism of such a disturbance has so far been elucidated only in the case of alcohol addicts where the group of retinene pigments is involved in the metabolism of ethyl alcohol (Trémolières 1955).

As another example we may quote the protective influence of vitamin C on experimental atherosclerosis as has been demontrated by the school of Mjasnikov (1954) and Aničkov (1953). As human atherosclerosis has a wavelike course with remissions and exacerbations of the pathological process, we can assume that an increased intake of calories and fat leads to a relative deficiency of this protective factor unless its intake is increased. From this point of view we can consider the seasonal deficiency of ascorbic acid (Šilink 1953, Křikava 1955, Scheunert 1956) which in Central and Northern Europe is fairly common as a permanent phenomenon of *partial hunger* during the winter months and an important factor which not only contributes to the well known "fatigue" in spring and the tendency to common cold, but also an arteriogenic factor due to a relative deficiency of vitamin C in the winter menu.

Many such examples could be quoted. We are, however, faced by the most difficult task if we attempt to define the role played by nutrition on the creation and maintenance of an *optimal state of health* of the individual and groups because the criteria of perfect and harmonious development of the human personality have not been defined.

Favourable nutritional influences are, no doubt, most important during the period of *youth*, when the dietary habits are formed and when the organism develops into maturity. For this reason, in assessing the influence of various factors, as with feeding experiments on animals, special attention has been paid to their action on growth and weight increase of the individual. The well known example of the Massai and Kikui shows the way: while the well nourished Kikui are strong and well built warriors, the semi-starved Massai are of small stature and poor farmers.

The second criterion of well balanced and adequate nutrition is *physical performance*. This includes, of course, also adequate defence and reparative reactions (Trémolières *et al.* 1952) of the organism (i. e. immunobiological, Trnka 1956), compensatory and adaptive (Hrůza, Fábry 1955), regenerative and reproductive functions).

The third criterion is the *state of higher nervous activity*. It has been proved that the ratio of nutrients in the total caloric intake can influence

the equilibrium of processes of excitation and inhibition (Makarichev 1950, Andriasov 1952, Lát 1955, 1956).

* * *

In most central European countries there are three main and fairly common nutritional deficiencies:

1. a small protein deficiency, mostly animal protein, particularly among adolescents,
2. a temporary deficiency of some components of the vitamin B complex and a relative deficiency of minerals,
3. a seasonal deficiency of ascorbic acid (vitamin C).

It is, of course, difficult to define the extent of these deficiencies and their importance because it is not enough to determine the difference between actual consumption and recommended allowance, but it is necessary to assess its biological significance. When defining the nutritional status we use, as has been mentioned, three criteria: growth, performance and higher nervous activity.

If we apply them, for example, to our findings in a group of adolescents investigated, it appears that the height/weight ratio in these adolescents was proportional to the intake of protein because in individuals with a high caloric but low protein intake this ratio is reduced by a disproportionate increase in weight. Some preliminary data from our nutrition surveys provide evidence for this assumption, though further investigations are wanted. Naturally this relationship prevails only in clinically healthy individuals provided that the vitamin D intake is fairly adequate and where the extreme variants of hereditary difference in stature cancel out.

More interesting and more controversial is the relationship between the level of blood pigment and protein nutrition. Gross protein deficiencies are manifested by a statistically significant decrease of the blood pigment and usually by microcytic anaemia. Total absence of animal protein (e. g. in so-called vegans — strict vegetarians) even by macrocytic anaemia (Wokes *et al.* 1955 a, b). It is, however, still doubtful whether nutritional factors (particularly protein and iron) can cause a recordable fluctuation of the haemoglobin level. Some preliminary data obtained by our nutrition survey group provide evidence for this possibility.

Another indicator of protein nutrition is, at least among adolescents, physical performance. The controversial opinions (Yudkin 1944) found in the literature led to a certain sceptical attitude towards performance tests which has been summarized by Sinclair (1948). These objections are certainly valid in the case of the mature individual where performance is associated with training and can be strongly influenced by motivation. We can, however, assume a different position in the growing individual: children living in the countryside get plenty of exercise and because they have roughly

the same opportunity for exercise and play — their muscular development depends primarily on the amount of building material available. When their nutritional status is low their activity and even their drive to play is lowered (Kraut 1955, de Castro 1952).

We investigated a group of children by means of the performance test (hanging on a horizontal bar) (Milligan *et al.* 1942) using our own modification (Křikava 1955). Our results showed an inverse correlation with the child's weight and a direct correlation with the protein intake and the Hb level.

The action of protein deficiency on nervous activity can so far be derived only from observations of so-called psychoses in internment and concentration camps and from data pertaining to metabolic influences on the central nervous system (Himwich 1941). Direct data have been provided by experimental work which shows that an adequate protein allowance in the diet of experimental animals leads to an increased activity and improves their ability to differentiate (Lát 1955, 1956).

Inadequate protein intake usually runs parallel with deficiencies of the B complex vitamins and some mineral elements. We observed that a sudden increase of the requirements of these factors leads to a slowing down of reparative processes in individuals, where the deficiencies were formerly only of subclinical order. Thus patients after surgical operations do not only exhaust their protein reserves but are also deficient in vitamin B_2 as manifested by typical symptoms of angular stomatitis.

Relative deficiencies of aneurin are accentuated at present by a decreased demand for high extraction breads and the increasing predilection for white bread as well as by the increased consumption of alcoholic beverages.

Subclinical ascorbic acid deficiencies have also a mass incidence and are marked in winter and spring when the supplies of fruit and vegetables are limited. Various authors provide evidence for these observations, though others quote different results (Bartley *et al.* 1953). It has been shown, for example, that in man even prolonged deficiencies of ascorbic acid are compatible with normal functions of the organism. We must, however, take into account that these experiments were of laboratory character and were done on formerly well nourished individuals. It proves that significant clinical symptoms appear only after ascorbic acid has disappeared from the tissues and has reached a zero level even in leucocytes, as has been postulated for years by Sinclair (1948).

* * *

Hunger — expect for some pathological states — is rare in central Europe. There are, however, many small nutritional deficiencies which escape the eye of the clinician. The rapidly developing science of nutrition will certainly help towards a better detection of these states which we consider subclinical at present and towards the elucidation of their pathogenic mechanisms.

If modern society is to protect man from partial hunger, it is faced with the foremost task of ensuring a level of food production which will provide an adequate allowance of nutrients and all biologically active elements. In addition there remains the task of health education: to further the knowledge of nutrition and to protect man from states, the chronic course of which, with their initially latent symptoms, undermines the health of the population.

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NUTRITION, TUBERCULOSIS & LIVING CONDITIONS

By Dr. E. Palermo, Argentina

Tuberculosis, persistent indication of social pathology, maintains its special position among the mass diseases. The history of the struggle against the "white pest" is a succession of periods of collective enthusiasm when a particular discovery concerning the etiology, diagnosis, prophylaxis or therapeutics encourages optimistic hopes of the speedy disappearance of the disease. This is what happened with the discovery of the bacillus by Koch, the discovery of tuberculin, the therapeutic pneumothorax, the application of BCG, and thus it has been in our days, as well, with the appearance of the antibiotics and antituberculous chemotherapy.

However, tuberculosis persists as one of the big health problems in all countries because, in spite of these promising successes of positive value, the close link between illness and living conditions has not been given the attention it deserves. This point has been made time and time again by authoritative medical spokesmen since Villerme in 1828 drew attention to the important evidence of living conditions/mortality figures in different social classes and Chadwick awakened an interest on the same point in the British Parliament in 1842.

Virchow in 1848 asked "*Why was disease — individual cases as well as epidemic forms — of a much more benign character than in the Middle Ages, when epidemics continued uninterrupted? Only because all classes of the population have reached a standard of living which excludes these diseases.*"[1] This relationship has been specifically demonstrated in the case of tuberculosis in innumerable published papers in scientific journals, and as well in conclusive form by the analysis of the mortality curve for tuberculosis. Among the social factors which most influence this curve, nutrition plays the principal part, as has been demonstrated by the sad experiences which different countries suffered in the two world wars.

The scant interest which social institutions have taken in these indications has bred disquiet in international medicine and has led to the Ist World Congress of Doctor for the Study of Living Conditions (Vienna 1935) and the further conference at Cannes in 1957.

It was to the merit of the Vienna conference that, in full awareness of the enthusiasm engendered by the use of tuberculosis figures, it revived the posing of the problem of the relations between illness and living conditions. This problem particularly affects countries such as the Latin American countries which suffer heavily from the burden of mass diseases, among which tuberculosis merits especial consideration.

It should be mentioned first that countries underdeveloped in other ways are also underdeveloped administratively, which means that they lack good statistics. For this reason, it is not possible to provide an adequate statistical basis for satisfactory scientific research. Nevertheless, the facts

are self-evident; each doctor has sufficient proof from his own experience and, in not a few cases, founded on partial statistics collected by doctors who have studied the problem in a specific locality and based almost exclusively on personal experience.

This lack of exact statistics is shown in the United Nations data. Thus, we see in many of these, that our country, Argentina, figures as one of the best fed in the world. Figure 1 will corroborate the international conception of the overfeeding of our people, where it is seen that Argentina has the greatest excess over *calculated* ration requirements *per capita*. Argentina in reality demonstrates, however, that this is true only for some groups of the population and not for the majority. The political, economic and social character of the country explains the reasons for this reality.

The Argentine Republic is a large country which, without the Antarctic, covers 2 795 695 square kilometres, with a population which does not even reach 20 million. The exploitation of the many national resources, which began in the colonial period, was slowed down and practically nullified at the end of this epoch by the political orientation which the interested cattle raisers in the littoral zone imposed on the republican organization. This explains how, in little more than a century of national history, the country has developed to the advantage of the littoral region and to the detriment of the rest of the country.

We still find the effects of this evolution in that 73·7 per cent of the population and the greater part of economic activity and exploited wealth is concentrated in the littoral which represents a quarter of the territory. From this region the conglomerate of Greater Buenos Aires projects as a great head, consisting of the Federal Capital and its suburbs.

The rest of the country fits Josué de Castro's description of the Latin American countries, as a "*distribution of effective humans in limited nuclei of population separated from each other by great, almost empty spaces*"[3] and, we would add, of economic development which varies but is always limited.

With such a demographic distribution, its economy, based fundamentally on the *latifundium* and single crop farming, is maintained with the hegemony of cereal and livestock production of which the major concentration belongs to the above-mentioned littoral, where what little national light industry there is, has also developed.

Excluding the littoral, the rest of the country can be divided into: a) a zone consisting of the north and west of the territory where the economy is based on the exploitation of regional single crops (sugar, cotton, yerba mate, tobacco, tannin, grapes) raised in general on great *latifundia* belonging to a limited number of people; b) the southern zone, which, with some single crops (fruit, vineyards) is mainly given over to the raising of sheep.

In both zones, at a lower level of development exist isolated areas of mineral development (oil, coal etc.) while the greater part of the mineral wealth remains unexploited. All these developments suffer from the effect of the great distances and the scarcity of means of transport.

FIGURE 1

Calorific rations calculated as a function of requirements
(calories per person per day)

Region and Country	Recent calorific ration	Requirement (calculated)	Difference (% of requirement)
FAR EAST			
Ceylon	1 970	2 270	— 13·2
India	1 700	2 250	— 24·4
Japan	2 100	2 330	— 9·9
Phillipines	1 960	2 230	— 12·1
MIDDLE EAST			
Cyprus	2 470	2 510	— 1·6
Egypt	2 290	2 390	— 4·2
Turkey	2 480	2 110	+ 1·6
AFRICA			
French North Africa	1 920	2 430	— 20·9
Mauritius	2 230	2 410	— 7·5
Union of S. A.	2 520	2 400	+ 5·0
LATIN AMERICA			
Argentina	3 190	2 600	+ 22·7
Brazil	2 340	2 450	— 4·5
Chile	2 360	2 640	— 10·6
Mexico	2 050	2 490	— 17·6
Uruguay	2 580	2 570	+ 0·4
EUROPE			
Denmark	3 160	2 750	+ 14·9
France	2 770	2 550	+ 8·6
Greece	2 510	2 390	+ 5·0
Italy	2 340	2 110	— 1·1
Norway	3 140	2 850	+ 10·2
United Kingdom	3 100	2 650	+ 19·6
NORTH AMERICA & OCEANA			
Australia	3 160	2 620	+ 20·6
United States	3 130	2 640	+ 18·5

This economic pattern of the interior results in an intra-national migration of population in search of work or better living conditions. It is estimated that such migrations affect some 25 per cent of the total popula-

tion of the country annually. Such a political/economic situation explains the existence of distinct levels of nutrition.

The lack of complete statistics and of global studies on nutrition should not invalidate the concepts suggested by the figures or partial research results available. With these it is possible to agree broadly with the classification which de Castro uses in his memorandum to UNESCO on 'Problems of Nutrition in South America'.[3]

Sector A corresponds in our country to the north-west and the south. It is characterized by a nutrition defective in quantity and quality which results in a state of marked under- nutrition and chronic hunger. This sector would include the majority of the population of 14 provinces, equivalent to a third of the country.

The province of Jujuy is a clear example of this sector. One of the latest reports on the nutrition of students, published in the *Primeras Jornadas Fisiológicas del Norte Argentine* (Jujuy 1956) by Dr. A. R. Carrizo and O. Marin,[4] reproduces without change the old denunciations made by R. J. Cárcano in his book "800 000 Analfabetos" (800 000 Illiterates) of 1933[5] and by A. L. Palacios in "El Dolor Argentino" (The Argentine Sorrow), 1937.[6]

It is revealed in these studies that the insufficient nutrition of the student population, consisting essentially of maize, beans, a few potatoes and occasionally dried meat, results in a poor state of nutrition which explains the high rate of mortality they suffer.

Sector B corresponds essentially to the already defined littoral, where the nutrition, in general sufficient in quantity, suffers qualitatively from partial scarcities, which together determine a state of discrete under-nutrition. Rich in meat and starch, deficient in milk, eggs, green vegetables and fruit. The consumption of meat, carbohydrates and milk for an important part of the 13 million inhabitants of this sector, raises the general average of calories *per capita*, which is used indiscriminately in the global statistics. But even thus a large percentage of this population — for economic reason — cannot reach this level as some studies show.

In a study on "the family budget and the nutrition of school feeding" of 1949, H. E. Guaita[7] tells us, with reference to the Federal capital "... *we can assert that the resources considered are in fact insufficient to cover the necessities of the typical domestic budget*".

"*We do not have recent nutrition research which permits us to draw conclusions at the present time but it must be taken into account that in our ten years' research, 30 per cent of the families, that is to say, approximately a third part have an unbalanced budget or are in debt*". (The research referred to was undertaken by the National Institute of Nutrition in 1939 on a total of 600 families in the city of Buenos Aires).

From a study of research into the nutrition of the infant before weaning, in the city of Buenos Aires, O. A. Abeyá in 1956[8] reached the conclusion that a high percentage received less than the recommended quantity of milk which, added to the other nutritional deficiencies, justifies a figure of over

18 per cent children suffering from malnutrition, who are also living in houses of unsound construction and lacking all hygiene facilities; all this added to the fact that more than half of the homes were in receipt of an insufficient monthly income which, according to the author, would explain the defective nutrition of such children. The importance of these figures lies in their corresponding to the numbers attending hospitals in greater Buenos Aires, which has the highest economic level in the country. In the same way, in Mendoza, which is also included in the sector of better economic possibilities, the following facts are given: E. Bustelo and his co-workers[9] in 1955 concluded from a study on "*the nutrition of the healthy child in the City of Mendoza*": "*From a clinical study it is deduced that some 64·2 per cent of the children would be in deficit in respect of the normal state of 'eutrophia'*". It is concluded that in the second year of life protective foods do not meet the minimum requirements. In the pre-school and school children, only 50 per cent have the necessary amount of protective foods, besides the contribution of butter, eggs and cheese being markedly sub-standard. Milk in general with us is bad, scarce and expensive. Official statistics reveal that the *per capita* consumption of fresh milk only reaches 83 cm³. "*The research has demonstrated the direct ratio existing between economic conditions and the quantity and quality of food*".

In a book by J. S. Maurin Navarro on "Schemes for Sanitary and Social Paediatry" (1956), among the socio-economic causes of the high infant mortality rate in the Province of Mendoza, the nutritional deficit is noted by the very great scarcity of milk which hardly reaches a daily consumption of 110 cm³ per person, and is not replaced by any other protective food of equal biological value. [10] Similar conclusions were drawn by S. Mayor[11] from his nutritional studies of schoolchildren in Valle de Calamuchita (Province of Córdoba).

From the broad view revealed by these limited regional studies, it is no exaggeration to affirm that more than a third of the Argentine population endure socio-economic conditions which produce a state of chronic hunger. Of the rest, the greater part suffer from slight subnutrition, a small percentage being left with sufficient food, and (of these) a minority are overfed.

This in a country of immense nutritional possibilities, where only half the cultivatable area is made use of, where the economic structure results in the export of a large quantity of the fruits of the earth which cannot be absorbed by the internal market, more and more impoverished by the persistent rise in the cost of living, and where one finds the contradictory facts, due to this same economic structure, of allowing the loss of part of the food produced, whether from speculation or through lack of transport (fruit, milk).

As already explained, the sanitary conditions are in turn a faithful expression of this economic structure. Taking the general mortality rate in different age groups, a definite difference can be seen between the two extremes: the worst example of Sector A — Jujuy, and the prototype of

Sector B — the Federal Capital. These figures demonstrate clearly that, while in the Federal Capital 50 per cent of the deaths are in the over 50 age group, in Jujuy 50 per cent die before they are five.

These figures confirm what happens with the infant mortality rate as, according to the technical studies of the United Nations, "*nothing is more revealing of the state of health of a community than its infantile mortality rate*". "*The infantile mortality rates reveal not only the lack of adequate health facilities for mothers and children, but also the existence of bad social conditions in general*".[2]

They also prove that, while in the Federal Capital the figures approximate to the acceptable for the normal leval of urban communities, the further we go from this centre, the more alarmingly high do the figures become. Thus, all the comparative figures combine to agree on this point. Look, for example, at the following table of mortality without medical attention.

Deaths at 0—1 year without medical aid[10]
(averages for 1951-53)

Administrative division	% of deaths from unknown causes
Buenos Aires	0·7
Mendoza	5·0
Santa Fé	6·6
Entre Ríos	13·0
Salta	37·8
Santiago del Estera	62·7

With respect to tuberculosis it is not to be wondered at that similar facts are repeated. There are no general statistics which allow the establishing of reliable figures but some rough estimates give us indications of a definitely morbid level. The tuberculosis mortality rate for the whole country is estimated at 35—40 per 100 000. While in Buenos Aires the figue is estimated at 16·9 per 100 000 (1·8 per cent of the total death rate), in the interior we find greatly increased figures which in Jujuy reach 175 per 100 000 (10 per cent of the total death rate (1955)).

The lack of statistics is more marked when dealing with general studies on tuberculosis mortality. But for our purpose it is interesting to compare the studies undertaken in different villages of the country, which, although they do not deal with homogenous groups of population, allow us for this reason to draw conclusions more related to our theme.

In the Federal Capital the statistics of tuberculosis mortality have been

worked out by R. F. Vaccarezza and B. Enquin in the Centre of University Prophylaxis (under Professor Vaccarezza's department of pathology and clinical diagnosis of tuberculosis).[12]

The low figures noted are influenced as much by the geographic origin of the students of the University of Buenos Aires, for the most part from the littoral, as by the economic standard of their families, in general from the middle or upper classes of the population. In contrast, in Jujuy which lies in the epidemiological stage of massive tuberculosis and whose nutritional poverty we have already described, the census of 11 500 school children of the whole province demonstrates the existence of high figures although varying according to the different provincial departments.

Tuberculosis morbidity discovered at the first examination

Tuberculosis morbidity	Period 1939—51 (62 926 students examined)		Period 1951—55 (62 209 students examined)	
	cases	%	cases	%
a) Tuberculosis not known to be active	330	0·52	184	0·30
b) Tb not recognized, suspected active	184	0·29	129	0·21
c) Tb diagnosed in treatment	121	0·19	91	0·14
d) Tb known, apparently cured . . .	82	0·13	102	0·16
TOTALS . . .	717	1·13	506	0·82

Department of Ledesma: from 25—35 per cent of school children under 12 years old are Tb positive;

10 per cent with active bacillus, many cavities.

Capital of Jujuy: 20 per cent Tb positive, 5 per cent with active forms (1956)[4].

On the other hand, the examination of 32 000 studies of the workers and their families in the sugar industry demonstrates an average of 13·8 per cent of progressive cases, reaching in some plantations the figure of 27 per cent (Jujuy 1957).

It is clear that in analysing these figures we have taken the extreme cases in the population — on the one hand, the population at a better economic level, where social influences are not important and, on the other, the Jujuy population with the worst socio/economic conditions in the country included in the sector where the mass diseases (Tb, trachoma, parasitism, Chagas-Mazza disease, ankylostomiasis, malaria, goitre, leprosy, Malta fever, syphilis) have the highest incidence, associated with illiteracy,

overcrowding, alcoholism and drug addiction — social ills, the eradication of which is not possible without somehow breaking the vicious circle: poverty-illness-more poverty — more illness.

In this vicious circle nutrition is the principal cause influencing even drug addiction.

Gutierras Noriega[13], who has studied the social origins of drug addiction, has maintained that "*the primary cause of cocaine addiction is the deficient supply of nutritional substances in the affected regions*". He establishes the following relation between the quantity of food ingested, calculated on the basis of information from S.C.I.P.A. (Interamerican Co-operative Service for Production of Food) and the taking of cocaine:

Consumption of leaves of cocaine

	Kilos per person per annum	Nutritional deficiency
1)	2—4	14·2%
2)	1—2	27·0%
3)	0—1	13·0%

These conditions given for the Republic of Bolivia, next-door neighbour to our province of Jujuy, are repeated for the most part by the population of that province, adding a new factor which adds to the Tb rate (in 1946 and 1947, Argentina imported from Bolivia 416 091 kg and 403 504 kg cocaine leaves respectively).[14]

Thus we come back to the nutritional factor as the most important element among the causes abetting illness, especially tuberculosis. It is clear that this is no chance but a variable depending on the socio/economic conditions.

The acknowledged importance of the nutritional factor in the struggle against tuberculosis without establishing the necessity of modifying living conditions by making practicable sufficient and balanced nutrition, and the changing of living conditions of our people, shows that we have to struggle for social evolution, based on an harmonious development of economic potentialities, which would make possible progress in the different conditions necessary for happiness: guaranteed employment, healthily and justly remunerated, development of culture, reasonable organization of effective health service etc. etc.

Any anti-tuberculosis campaign ought to include among its objectives, along with vaccination, BCG, early diagnosis, prophylaxis etc., and as a fundamental requirement, the assuring of adequate food to the population as defence against the disease. There can be no doubt of the necessity of this essential factor which ought to be the standard for societies organized for effective progress in matters of health. But these societies will not adequately achieve this objective if the techniques of health do not act in a more decisive form.

We maintain that doctors in general, through their scientific, trade union and cultural organizations, ought to exert a more effective influence as an organized force for the defence of health and the wellbeing of the people. This is the practical way to achieve the concept of health as defined in the preamble of the constitution of the *Organización Médico Social* (Argentina): "*Health is the state of complete mental, physical and social wellbeing and not merely the absence of illness or infirmity*" which is complemented by the recognition, in the Declaration of Human Rights proclaimed by the United Nations, that "*Everyone has the right to a standard of living adequate to secure for himself and his family, health and wellbeing, and especially, food, clothing, accommodation and medical assistance*".

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PHOTOSYNTHESIS AND THE PROBLEM OF FOOD RESOURCES

by

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At the root of technical progress, prosperity, and the very life of man lie three fundamental problems: 1. The problem of food and food resources; 2. The problem of energy and power resources; and 3. The problem of technical materials.

The most important and the most acute of these is the problem of food resources which is wholly based on the photosynthesis of green plants. The photosynthesis of green plants is practically the only primary source (with the exception of chemosynthesis, the extent of which is insignificant) of the new formation of organic substances, and hence it is the sole *primary source* of food for all living organisms on earth, including man.

Taken together, all the plants on the globe both on land and in water produce annually about 450 billion tons of organic substances, which is roughly 180 tons per inhabitant of the earth. This is done in the process of photosynthesis from carbon dioxide, water and mineralized compounds of nitrogen, sulphur and other elements.

Yet, despite this fact, the food problem is one of the most acute problems facing mankind. Its acuteness — even to the point of its becoming a national calamity — is especially felt in countries with underdeveloped agricultural techniques or in years of drought and difficult wintering conditions, or when harvests are attacked by pests and plant diseases.

One of the reasons for the problem of food resources being acute is the extremely uneven distribution of food products among the inhabitants of different countries and among the various strata of society within a country. However, even if all the food products produced at present by man were distributed uniformly, the total world population would not at present be fully supplied with food of the required quality.

In the final analysis, the present and future of mankind, the limit of the population level of the earth and the level of prosperity of the individual depend entirely upon the potential production of the photosynthesis of plants on the earth and upon how fully and rationally man is able and willing to realize and utilize these possibilities.

It is precisely for this reason that the problem of the photosynthesis of plants as the primary basis of man's food resources is one of the most important and most topical problems of modern times, and of future times for that matter.

This is the viewpoint from which we shall discuss the problem of food resources. The view is not infrequently expressed that the problem of food

resources will receive entirely new possibilities for its solution when we have discovered all the peculiarities of the mechanism of photosynthesis of plants, and are able to make this mechanism work in artificial industrial systems.

Without a doubt, a full knowledge of the mechanism and principles for accomplishing natural photosynthesis will carry with it tremendous consequences for the theory and practice of chemical science and industry.

However, it is worth reflecting upon the nature of these consequences. First of all, it must be pointed out that no artificial photosynthesis will be capable of creating food products so diverse in kind, so complex in composition, and so agreeing with the tastes and requirements of man, as flour, vegetables, fruits and so forth.

Consequently, when speaking of artificial photosynthesis we might hope to benefit by it only insofar as the production of individualized food substances, as for instance, carbohydrates, fats, nitrogen-containing substances (amino acids, proteins) or substances of high physiological activity as vitamins, hormones etc., is concerned. However, if we begin to speak of such products as carbohydrates, fats and proteins, we note that they are required in such tremendous quantities that their artificial photosynthesis would only be significant if the process could be accomplished on a very wide scale, comparable to that of plants.

If such a synthesis were organized to utilize the energy of the sun's light, the necessary apparatus would have to have a large surface to entrap the sun's rays. This surface would have to cover tens and hundreds and even thousands and tens of thousands of hectares (1 hectare = 2·471 acres). To carry out complex synthesis, such apparatus would have to be complicated in design and construction. It would also have to be capable of continuous operation.

The ideal system of continuous operation is the photosynthesis mechanism of plants. Its work is fundamentally different from the majority of ordinary industrial and preparation reactions.

The process of photosynthesis is accomplished as a continuous process in extremely complex structures: cell-chloroplast-granule, with a complex system of such catalysts as chlorophyll, various carriers of electrons and hydrogen, diverse enzymes, acceptors of CO_2, etc.

Recent research using tracer techniques has shown that many of these agents are constantly being consumed, renewed and recreated in the process of photosynthesis. Thus, the Soviet investigators T. N. Godnev and A. A. Shlyk, and also F. V. Turchin showed that chlorophyll and proteins are subject to constant renewal, and the intensity of metabolism depends on the intensity with which the photosynthesis apparatus operates.

This probably also applies to many other important components of the process of photosynthesis, such as the enzymes. Thus, the characteristic

peculiarities of natural photosynthesis as the most perfect mechanism o continuous action are: a constant self-reproduction of the photosynthesi apparatus, a constant recreation of active systems that are necessary fo its operation, and at the same time a constant removal of products produce in excess, to zones of consumption for growth or for building up reserves

From the foregoing it is not difficult to visualize the complexity of thi apparatus, to imagine the tremendous diversity of the reactions that i must provide and the strict co-ordination that must be ensured for it t function normally. And if all of this was developed and created in th process of plant evolution during millions and even billions of years, i can hardly be hoped to create artificially just such a complex self-renewin mechanism of continuous action, which of itself would not only renev itself as it works but would also reproduce and grow, covering huge area and taking up stupendous quantities of solar energy and working on a scal just as grandiose as do plants that cover vast expanses of the globe.

Of course, this in no way signifies that knowledge acquired of the orga nization and mechanisms of natural photosynthesis cannot lead to con sequences of great importance theoretically and practically. There can b no doubt that a thorough knowledge of the mechanism and nature of photo synthesis could help to revolutionize our chemical industry. For exampl many chemical processes which are at present accomplished by applicatio of energy (high temperatures, pressures etc.) will in future proceed a photochemical reactions deriving energy from sunlight, that is, they wi operate on a practically limitless power basis. And the range of possibl reactions that may be accomplished in this manner is infinite.

By selecting the optically suitable and active sensitizers (chlorophyll i green plants) and catalysts (enzymes in plants), any substances may l brought into the reaction, irrespective of their optical activity and chemic stability, and these reactions may be carried out with high material an energy yields. This statement is based on the fact that in the reaction photosynthesis of plants there participate such optically inactive and ch mically extraordinarily stable compounds as carbon dioxide and water, ar in a number of cases mineralized compounds of nitrogen, sulphur and other while the reaction products are diverse and complex organic substance

Thus, natural photosynthesis may teach us how to carry out many im portant industrial reactions on the basis of photochemistry and the utiliz tion of the energy of solar radiations. These reactions will of course relatively simple in composition. In not all cases will these be process of continuous action, and there is no doubt that artificial photosynthes will never be able to take the place of natural photosynthesis, either qual tatively or quantitatively, as a means for providing human beings an animals with food and forage.

Precisely for this reason, the future of mankind will depend first of and most acutely upon how successful man is in progressively increasi

the photosynthetic output of the green plants themselves. Man has at his disposal two principal possibilities of solving this problem in full for the present and the future.

The first consists in a maximum increase of the efficiency with which the photosynthetic process is utilized by natural vegetation (forests, steppes, meadows, and marine vegetation) and the fauna which exists on the basis of this natural vegetation.

However, *a radical solution of the problem may be achieved only by the second path, that of expanding the area under proper and intensive cultivation of the most valuable and productive food and forage plants, the photosynthetic productivity of which is usually considerably above the productivity of plants of the natural coenoses, and by increasing in every way their yields and food productivity.*

The decisive significance of this latter possibility is once more stressed by the fact that thereby there is established between plants and man the most simple type of food chain, where man himself consumes directly a considerable part of the vegetable food products: a certain portion of the vegetation is converted into high-quality food products through the agency of only one intermediate biological link, domestic animals. And only in a small part is there yet another intermediate link, that of micro-organisms (as in siloing, leavening, fermentation).

The remaining organic substances, such as vegetable remains, the offal of animals (aside from the part lost in the form of such technical products as fibres, wool etc.), are returned by man to the soil in the form of organic fertilizers, thus increasing the quantity of photosynthetic product in subsequent cycles. This is also especially important for obtaining high yields at present and in the future.

This type of system provides for a high total level of produce and a high degree of efficiency in man's utilization of the photosynthetic produce of plants as a source of food. Considerably less effective in this respect are the natural coenoses. First of all, because they include plants that are of little or no value as food or forage, and secondly, because they are not so intensively used. The value of many of them lies chiefly in their use as a source of technical materials, forests being a fine illustration.

To summarize, *the tendency in the future development of the problem should be to replace gradually the natural coenoses on the land areas of the globe with cultivated crops and tree stands of the most needed and highly productive plants, and to make the food links between plants and man as short and effective as possible.*

This applies first of all to the steppes, meadows, swamps and slightly exploited forests, especially in the tropical and subtropical zones with their high degree of humidity and long vegetative period.

It is possible to obtain extensive areas for cultivation of food and forage plants by irrigating the lands of deserts and semi-deserts. The success and scale of this measure will in large degree depend on how the power problem is solved. The more technical energy man has at his disposal, the greater will be the areas that can be irrigated not only by natural flow (through the use of dams and canals), but also by pumping water into zones of insufficient humidity from rivers and lakes situated in zones of excess humidity.

Large quantities of available power would make it possible to extend appreciably the cultivation of plants in open, heated ground or closed ground with partial artificial lighting (light cultivation), which is particularly important for the northern and polar regions of the globe. It must be stressed at this point that, as far as possible, the power problem must be solved to ensure an absolute and relative growth in the use of hydroelectric and atomic power, the energy of the tides and solar energy, and also a relative and absolute reduction in the power obtained by burning coal, petroleum, gases, peat and other materials of photosynthetic origin.

These are the materials which in the future will to a great extent be used to solve the problem of the artificial synthesis of technical and chemical materials. Coal, petroleum, gases and non-food vegetative remains can and must serve as a source for the synthesis of rubber, plastics, technical oils, dyes, substitutes for fibres, wool etc.

The future development of the problem of power and technical materials in this direction can materially reduce (and may be entirely supplant) the cultivation of many technical plants, thus extending the possibility of cultivating plants for food and forage. If we call to mind the rubber-bearing plants, dyes, a number of essential oil plants, and medicinal plants, if we take into consideration the tremendous progress of technological chemistry for instance in the production of plastics, dyes, and so forth, and if, finally, we recall that at present extensive areas and, at times, some of the most valuable lands are being used to grow cotton, textile plants, rubber-bearing plants, and many others, the conclusion may be drawn that development of this problem in the direction suggested can open up great possibilities for increasing the cultivated areas of food and forage plants.

Rough estimates show that all the above-mentioned measures could increase from 5 to 8 times the areas now under cultivation with food and forage plants.

In addition, the food resources of man can and must be increased by means of raising the photosynthetic productivity of plants and by raising their yields.

The process of photosynthesis and the photosynthetic apparatus of plants are responsible for the formation of 90 to 95 per cent of the total dry mass of harvests and for their storing of all that potential chemical energy. For

this reason, progress in the field of agriculture may be most rapid and effective if in working out and evaluating each procedure aimed at increasing crop yields we proceed from a clear understanding of how it influences the plant, and the utilization of the products of photosynthesis by the plants themselves for such processes of growth and life activities as can lead to the highest possible yields of highest quality.

To obtain high and stable yields according to plan, it is necessary that the formative processes and work of the photosynthetic apparatus of plants (the leaf area) should proceed according to optimum schedules throughout the vegetative period.

An idea may be gained of the theoretically possible harvests of plants and their conditions of growth if we proceed from estimates of the optimum course of development of the photosynthetic apparatus of plants in crops and tree stands and the resulting potential capacity for work. These collected data may serve as a basis for the theory and practice of obtaining high crop yields.

Some of the principles deduced from work conducted in this direction in the U.S.S.R. are presented in this paper. More detailed figures on this question are given in a book by A. A. Nichiporovich.*

Only crops and tree stands which develop a large leaf area capable of assimilating large quantities of carbon dioxide, are able to produce high crop yields. But at the same time, the leaves of plants (the organs of photosynthesis) require good illumination to function normally. In ordinary conditions, a sufficiently good illumination of the leaves may be provided when the total crowding of the crop or coenosis is not too great; if the leaf area in crops becomes too great owing to overcrowding and resulting increase in humidity with an excessive and overbalanced supply of nitrogen, the leaves of the lower layers find themselves in conditions of insufficient illumination and rapidly yellow and die.

This causes accelerated growth of the stalks with the appearance of new top leaves, and not infrequently leads to falling over of grain and cotton, to excessive leaf growth in potatoes, to deterioration in the formation of grain, fruit, tubers, root crops, and in the qualities of these crops (the content of starch, sucrose, oil etc.), and therefore reduced or low-quality crop yields.

Experience shows that for such crops as wheat, maize, potatoes and sugar beet, the optimum growth of leaf area may be regarded as 5 to 6 thousand m^2 per hectare on the twentieth day after germination, about 20 to 25 thousand m^2 per hectare on the fortieth day, and from 30 to 40 thousand m^2 per hectare on the sixtieth day. After this the leaf area should be maintained for a certain time at this level (the duration of this period differs for dif-

* "Photosynthesis and the Theory of Obtaining High Crop Yields", *Moscow Acad. of Sciences, U.S.S.R.*, 1956.

feeren plants); then it should begin to decrease due to progressive dying off of the leaves, and the transfer of substances used for growth and storage in the fruit, grain, tubers and root crops.

In modern crops under normal conditions (not crowded and with sufficient supplies of water and nutrients), the average productivity of photosynthesis is about 4 to 5 g dry substance per m^2 leaf area per 24 hours. Given the optimum formation of leaf area in crops with these figures of photosynthetic productivity, the biological yields obtained of plants with a vegetative period of 100 days will amount to about 8 tons of dry weight per hectare, whereas plants with a vegetative period of 120 to 150 days produce approximately 12 to 15 tons.

This corresponds to a wheat harvest of approximately 25 to 30 centners per hectare, and that of potatoes or beet of 300 to 450 centners per hectare. These are not bad harvest yields but they are not such as can fully satisfy us, and the aim of our efforts should be considerably better yields, which in some instances have already been achieved.

The natural question that arises is: how can the photosynthetic apparatus of plants be acted upon in order to increase yield? We have already noted that growth of the leaf area is optimal; a further increase in yields may be obtained, therefore, only by increasing the net productivity of photosynthesis.

What are the possibilities in this direction and, in particular, what is the theoretically possible maximum productivity of photosynthesis? Its theoretical limit is determined by the minimum required quantum consumption of the photo stage of the process and the quantity of energy of solar radiation obtained by the crops and tree stands.Energy studies of photosynthesis show that normal photosynthesis may be regarded as proceeding with a quantum consumption of 8 to 12 quanta of absorbed light (from the photosynthetically active part of the solar spectrum). Given an average intensity of the total solar radiation of 0·7—0·8 cal/cm^2 min, this can produce an intensity of photosynthesis of 100 to 150 mg CO_2/dec^2 of leaf surface per hour. Figures close to 100 mg CO_2/dec^2 per hour have been recorded in the literature, which fact confirms, in principle, the possibility of such intensive photosynthesis.

However, the observed intensities of photosynthesis are equal to 12—20 mg CO_2/dec^2 hr, while the diurnal assimilation of CO_2 = 10 to 15 gr CO_2per m^2 of leaf area. These figures correspond to those mentioned above for a net productivity of photosynthesis of 4 and 5 g of total dry mass per m^2 of leaf area per 244 hours. However, in modern crops we not infrequently observe photosynthesis intensities of 25 to 35 mg CO_2/dec^2 per hour, or a diurnal assimilation of 30—40 gr CO_2 per m^2 of leaf area per day, which corresponds to 10—12 g of total dry weight per m^2 of leaf area per day, which corresponds to 10—12 g of total dry mass per m^2 per 24 hours for pure productivity

of photosynthesis, which is from two to three times as great as that ordinarily found.

With such characteristics and with optimum growth of leaf area, it is possible to obtain cereal yields of 60 centners per hectare or 700—750 centners per hectare of tuber and root crops.

If the intensity and productivity of photosynthesis correspond to those theoretically obtainable (that is, if the process of photosynthesis proceeds with a 10 to 12 quantum consumption) it is possible to obtain biological plant yields, with a vegetative period of 100 days, of 20 to 25 tons of total dry mass, while for plants with a vegetative period of 150 days the total may reach 50 and 60 tons, which may correspond to yields of 100—120 centners per hectare of grain or 1 200—1 600 centners per hectare of tuber and root crops. At present, record crop yields have been registered that are close to these.

These theoretically possible harvests are 4 to 5 and even 10 times higher than the usual yields obtained at present. In other words, a rise in plant yields to the theoretically possible level could increase agricultural produce five — and even ten-fold. However, these theoretically possible yields are possible only under favourable conditions which cannot be provided for at all places and every year, owing to insufficient water supply, difficult wintering conditions, pests, low soil fertility, and so forth.

Still, a future increase in yields of three and four times over present-day standards may be considered as entirely possible and realistic. This aim, however, can be reached only by tireless efforts to raise the photosynthetic activity of cultivated plants. One necessary step in this direction is the strict selection of forms and varieties of plants with higher than usual photosynthetic activity, so that the actual photosynthetic work of their leaves approaches or nearly reaches the theoretically possible level.

With this purpose in mind, the material being selected should undergo special physiological tests. A simple method of evaluating such varieties should be the selection of forms which show the highest ratios between the weight of the economically valuable organs (grain, tubers, root crops) and the leaf area. If we make use of all these possibilities (that is, increase in yields, extension of crop areas and improved methods of cultivation), we may hope finally to increase our food resorces at least 20 and maybe even 40 times.

These, however, are probably not the only possibilities of increasing the photosynthetic production of plants, since a considerable part of the food products of man are obtained and may be obtained from the oceans, seas and inland waters.

Potentially speaking, the oceans and seas could serve man as a tremendous source of food materials: firstly, because their area is over 2·4 times that of the land, and secondly, because owing to exceptionally favourable conditions of life, the average photosynthetic productivity of marine plant

organisms (chiefly phytoplankton) is great, over 1·5 times the mean photosynthetic productivity of terrestrial plants. Unicellular algae of phytoplankton of the oceans and seas makes up 80 per cent of the organic substances produced on the earth in the process of photosynthesis.

However, the productivity of the seas and oceans as a source of food products for man is substantially below that of the crops of cultivated plants on land, due to the more difficult and less intensive methods of farming the seas and oceans. A more important reason lies in the very nature of the living world of the seas and oceans. Thus, the algae of marine phytoplankton multiply and die and partly fall to the bottom where they are inaccessible to the biological cycle as food material. Besides, as a rule, man hardly utilizes marine plants at all directly either as food for himself or as forage for domestic animals. The food man gets from water is fish and other animals, the overwhelming majority of which do not feed on vegetable food, but on the lower-organized or smaller animals, with respect to which they are predators.

Thus, the relations between marine plants and man are in the form of complex and multi-stage food chains, in each link of which there occur big and irreversible losses of organic matter in the formation of remains and wastes that rapidly fall to the bottom or are decomposed by microorganisms. Thus, what man gets is an insignificant part (a hundredth or so part of one per cent) of what marine plants create in the process of photosynthesis.

The method of development of the problem under discussion should be to make a detailed study of the photosynthetic productivity of marine plants, to find ways of increasing it, to study and control the food chains in water, and, finally, to find ways and means of simplifying these chains as much as possible, thus making them highly productive from the viewpoint of man's interests. The closest to this ideal is pond economy, where cultivated species of fish, for example, carp, are grown, and where the food chains are relatively simple and the photosynthetic productivity of the phytoplankton is maintained at a high level by using fertilizers.

It is difficult as yet to say to what degree this work will raise the photosynthetic and nutrient productivity of bodies of water. But it is clear that in future this productivity can be increased appreciably. In connexion with this problem it is worth mentioning the attempts at mass cultivation of unicellular algae now being carefully studied by investigators in many countries. Such experiements are undoubtedly of interest and worthy of careful study. However, they may be regarded only as an auxiliary method of solving the problem of food resources, and for the following reasons: the theoretically possible produce of high-yield producing terrestrial plants and *Chlorella* do not differ radically. For example, the possible annual productivity of *Chlorella* is 70 tons per hectare of water, whereas that of terrestrial plants is up to 60 tons, and record yields have already been

registered of sugar cane and sugar beet for forage that are close to this figure. The cultivation of terrestrial plants is simpler and can be accomplished on a much larger scale than that of *Chlorella*, and terrestrial plants are capable of producing more nutritious food materials.

However, in certain conditions (for example, lack of land, the possibility of building reservoirs for cultivation on roof tops of buildings), and especially in desert areas, where there is abundance of light, it will be possible to obtain considerable quantities of organic substance (primarily as forage for animals) even under conditions of limited supply of water (if its circulation is in closed systems).

Thus we see that the future is very promising and that man has at his disposal inexhaustible possibilities for a solution of the problem of food resources that will supply him with high-quality food products for an indefinitely long period of time. The realization that nature opens up to man practically boundless possibilities should imbue us with the feeling that the food problem can be resolved not by the attempt of some to utilize the present limited resources at the expense of others but by common, friendly and co-ordinated efforts to wrest from nature what she offers man in sufficient quantities.

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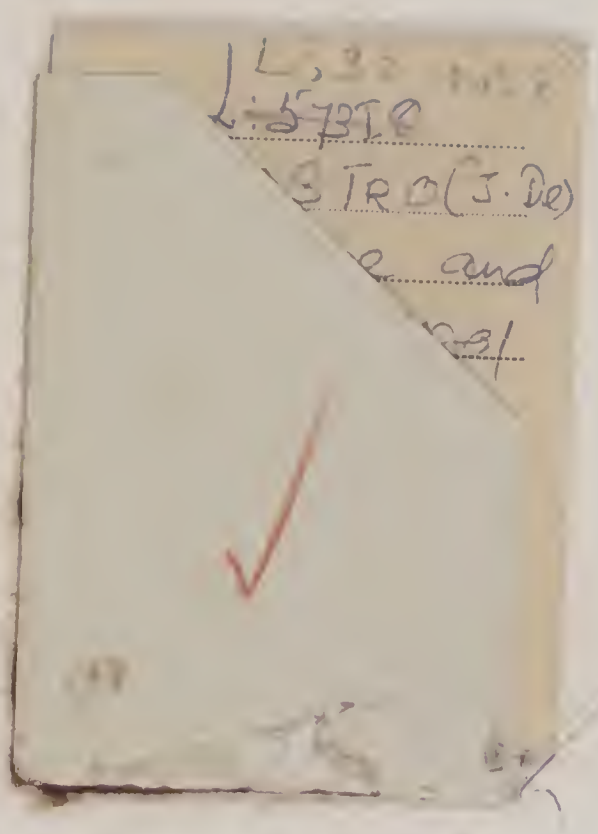
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